Tappi

THE JOURNAL OF THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

APRIL 1960

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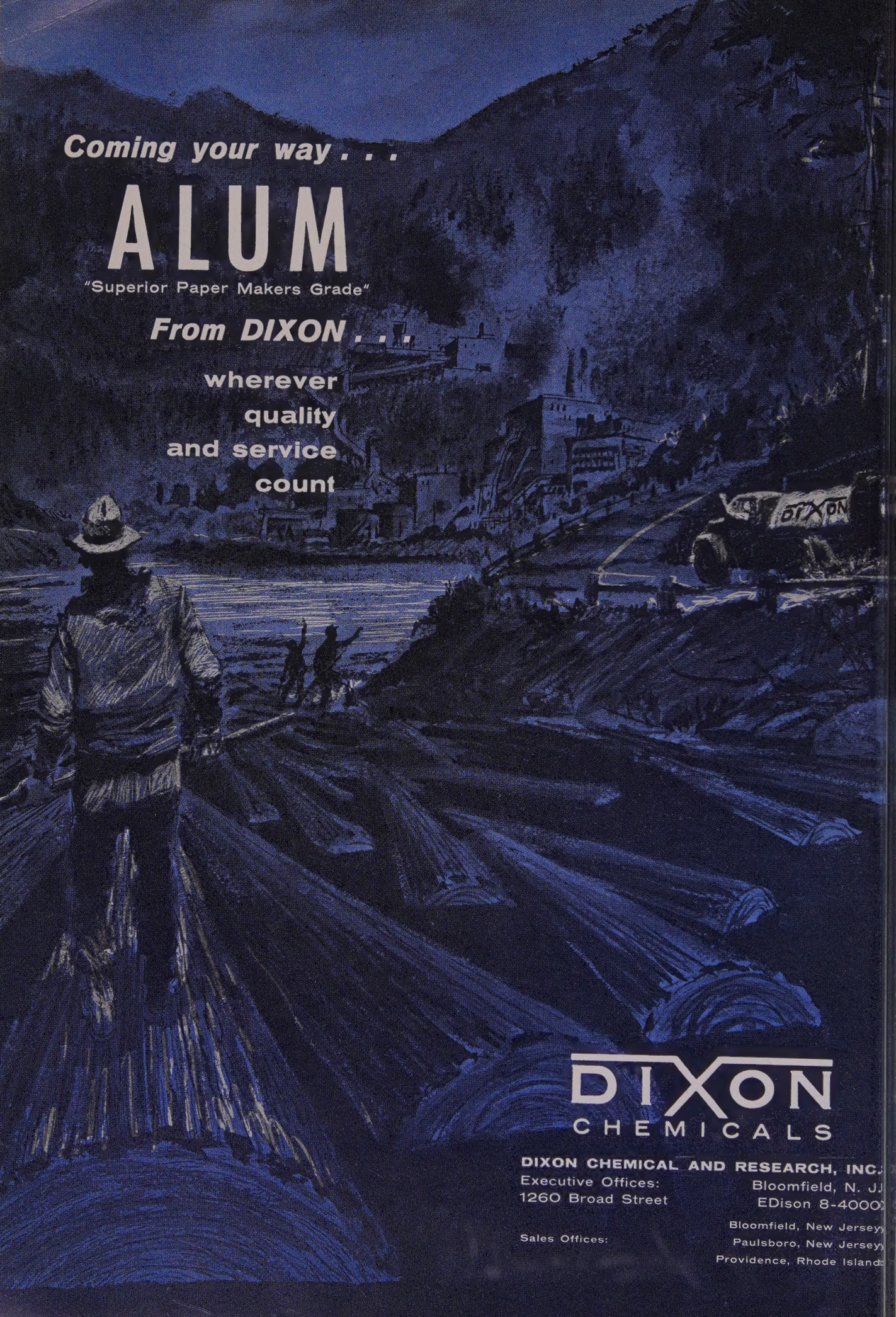
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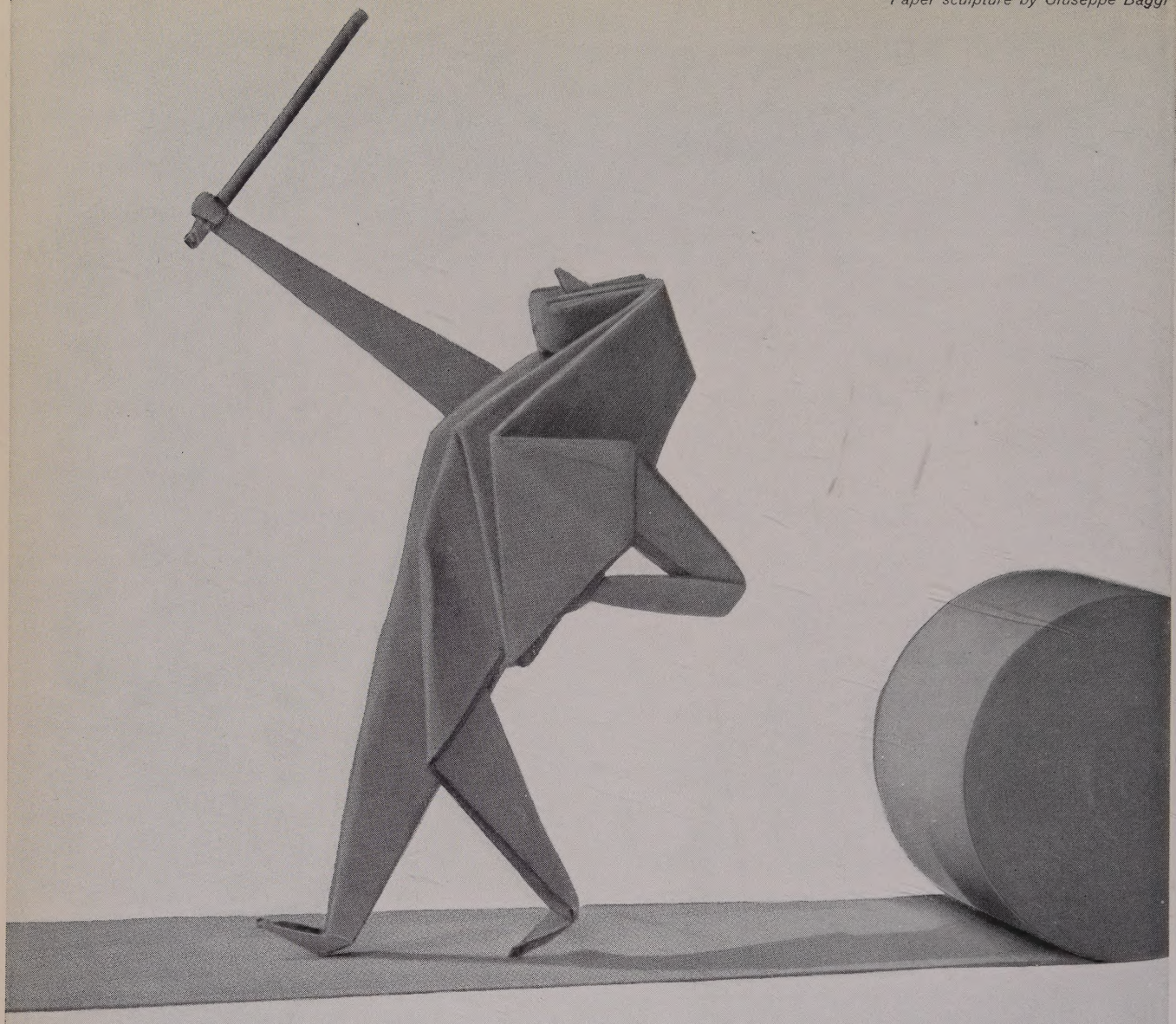

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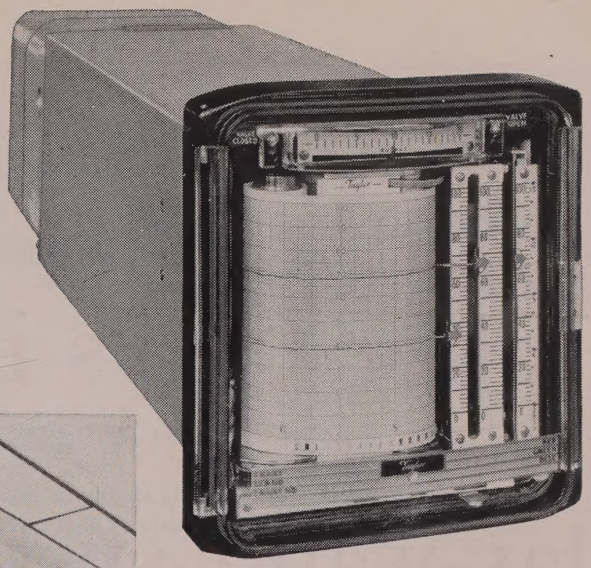

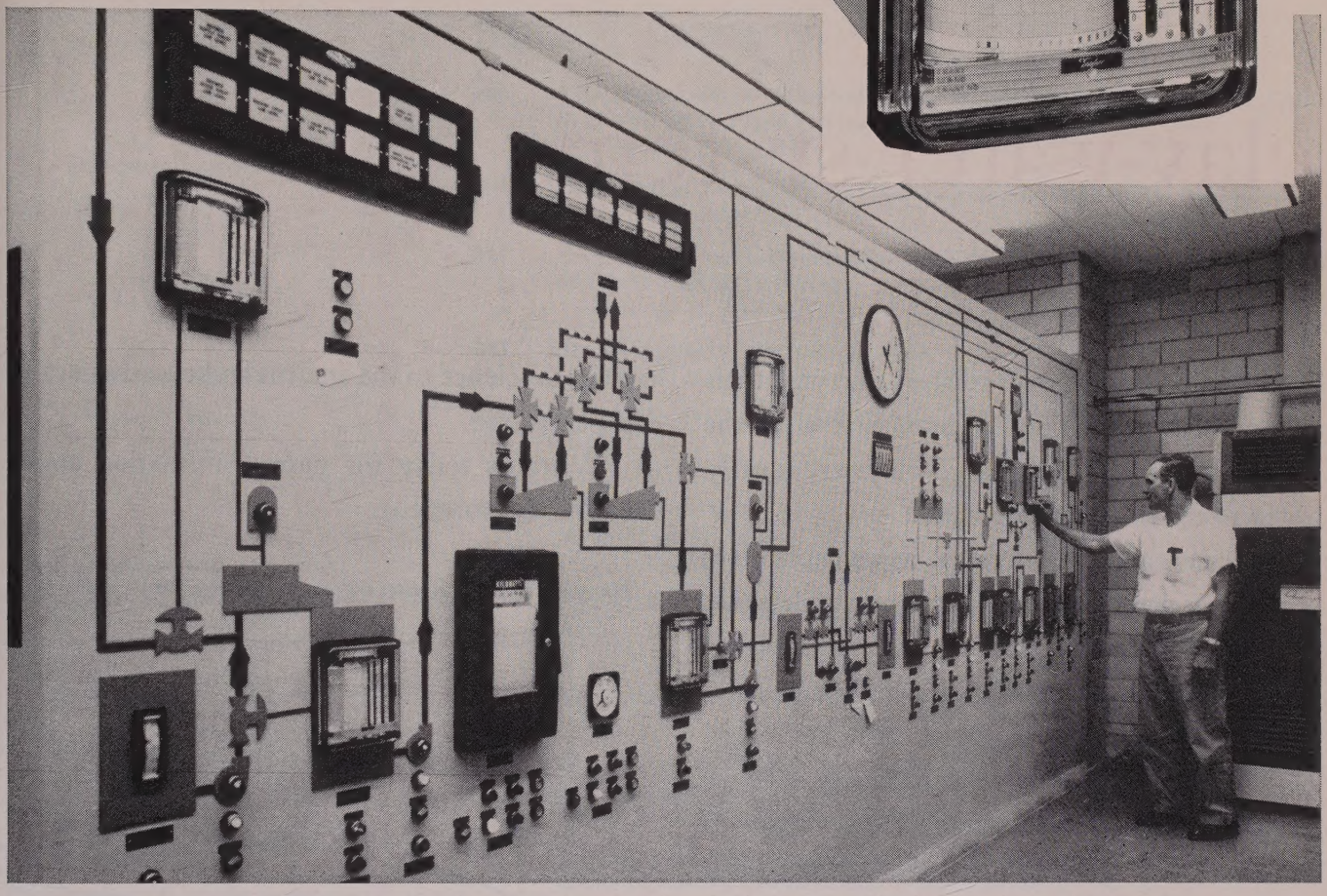

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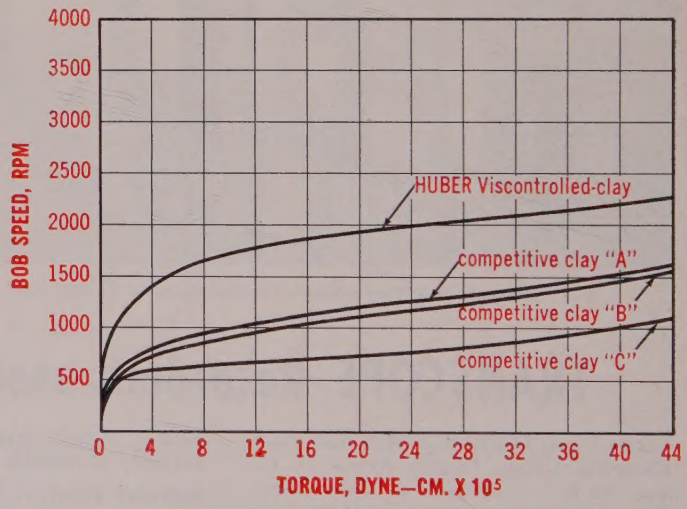

Rheogram shows superior properties of Huber Viscontrolled-clays at high shear rates.

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EDITORIAL DIRECTOR
R. G. MACDONALD

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ASSISTANT EDITOR
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Eleventh Coating Conference
Edgewater Beach Hotel, Chicago, Ill.
May 23–25, 1960.

Pulp Bleaching Conference
Edgewater Beach Hotel, Chicago, Ill.
June 14–16, 1960.

Fourteenth Alkaline Pulping Conference
Multnomah Hotel, Portland, Ore.
Aug. 22–24, 1960.

Forest Biology Conference
Seattle, Wash.
Aug. 24–27, 1960.

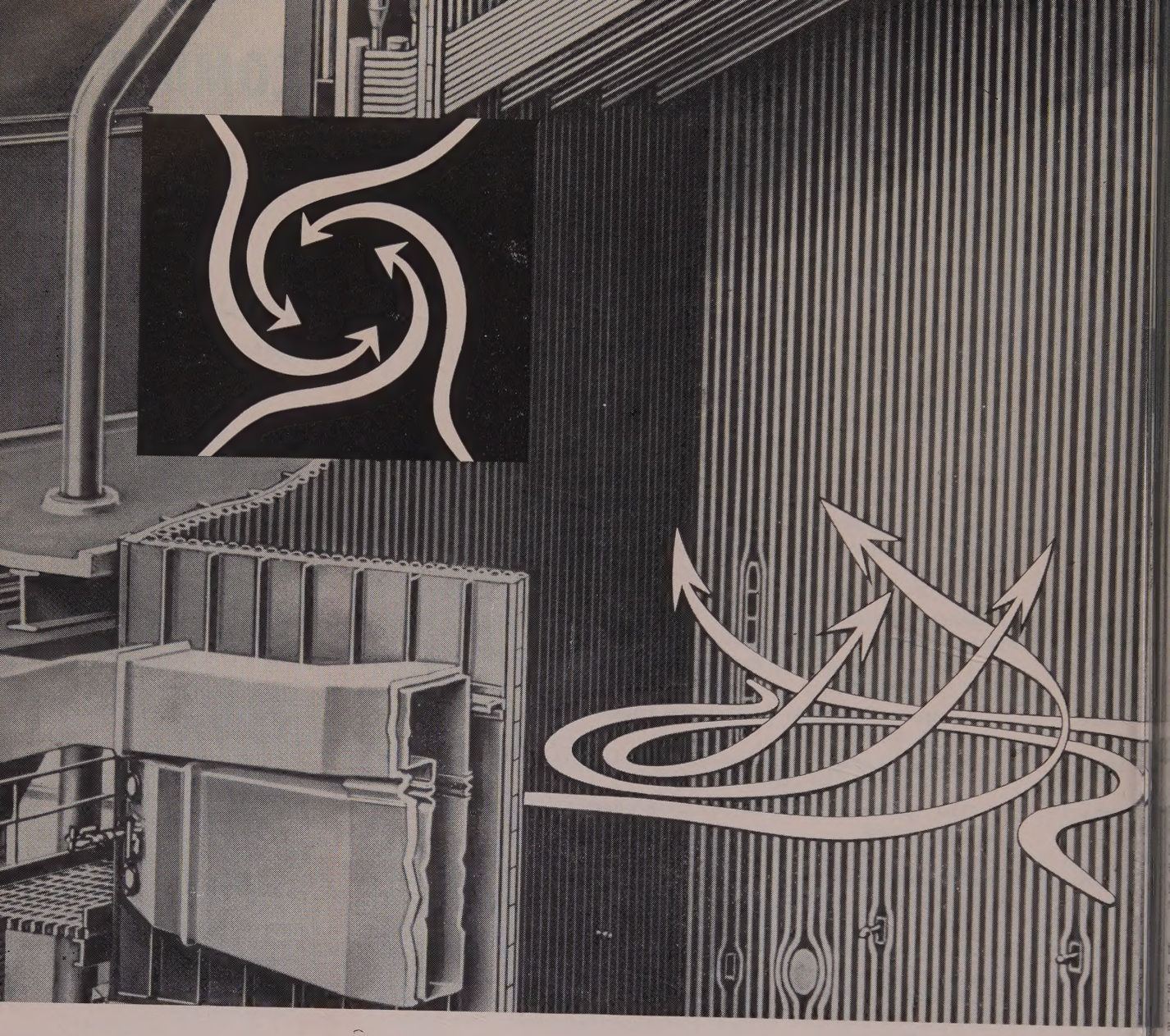
Eleventh Testing Conference
Pantlind Hotel, Grand Rapids, Mich.
Sept. 27–29, 1960.

Tenth Corrugated Containers Conference
Royal York Hotel, Toronto, Canada
Oct. 10–13, 1960.

Fifteenth Plastics-Paper Conference
Hotel Syracuse, Syracuse, N. Y.
Oct. 17–19, 1960.

Fifteenth Engineering Conference
Robert Meyer Hotel, Jacksonville, Fla.
Oct. 24–28, 1960.

Please refer to Local Section Activities for the locations and dates of Section meetings



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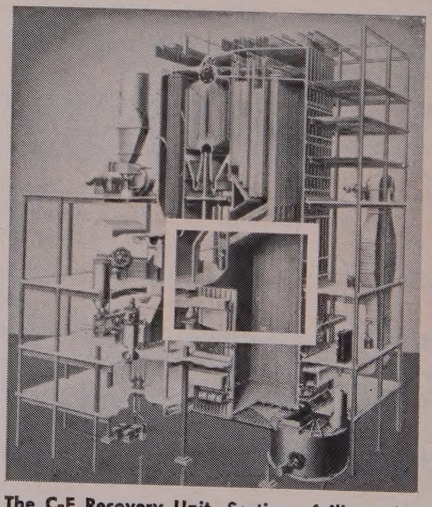

The C-E Recovery Unit. Section of illustration has been enlarged to show the upward-spiralling gas path produced by C-E's exclusive *tangential* introduction of secondary air. Inset (above, left): diagram of tangent principle.

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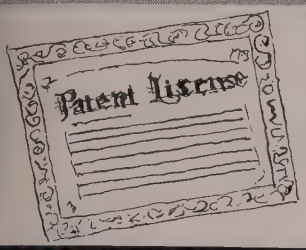

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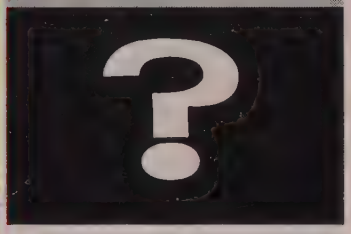

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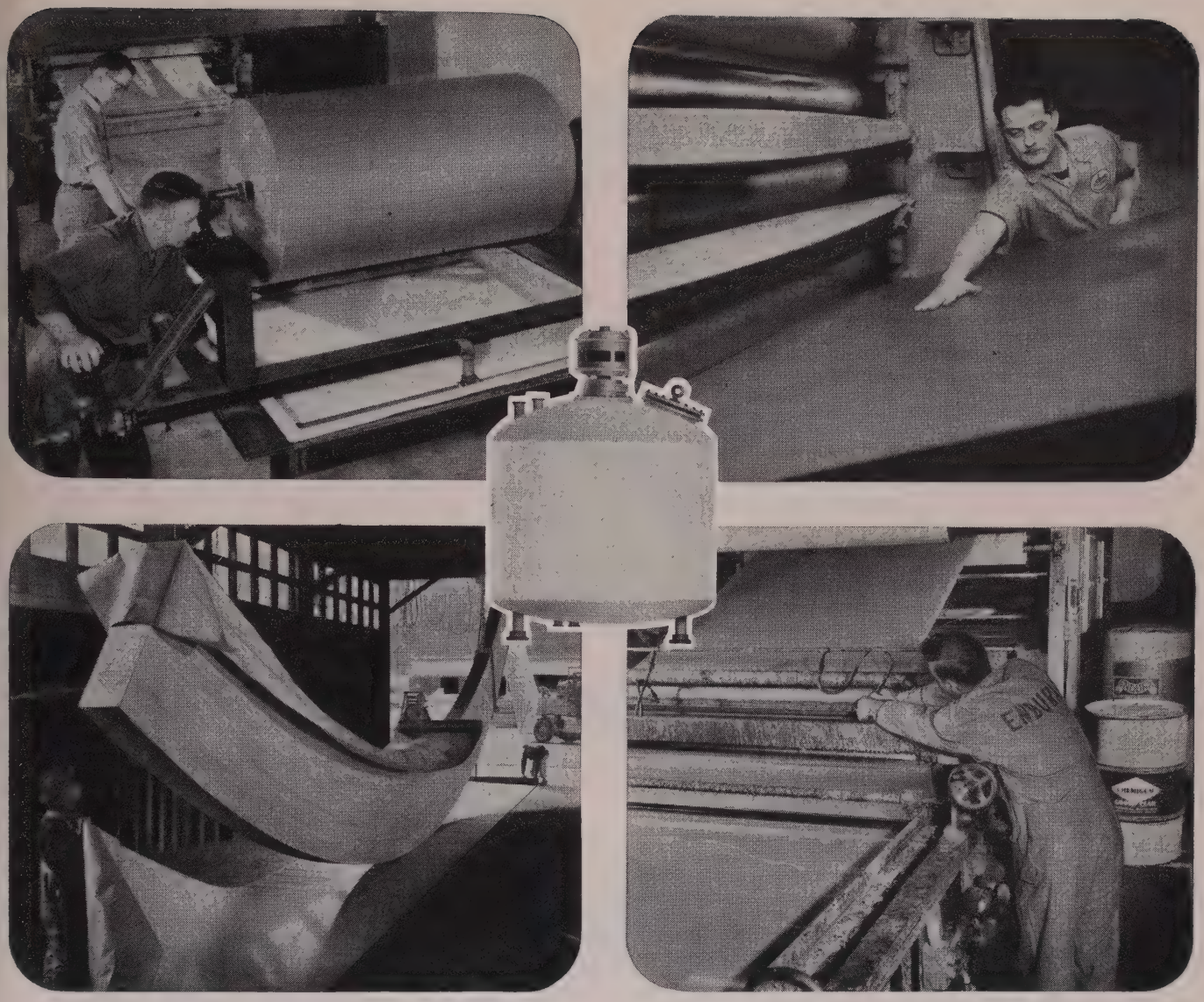

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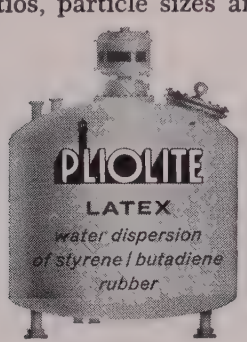

GOODYEAR

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Tall Oil Industry

JOSEPH M. WAFER

In order that we may be in complete agreement as to the product or products under discussion, tall oil is officially described as follows:

"Tall oil comes from the pinewood used to make sulfate pulp. The highly alkaline chemicals used for pulping convert the fats and resin in the pulp wood into soaps and these are skimmed from the spent liquor. Tall oil results when the soaps, or skimmings, are acidified. The product, known as whole or crude tall oil, is often further processed to alter its properties or its chemical composition.

Whole tall oil is a mixture of rosin acids and fatty acids with minor amounts of sterols, higher alcohols, and other nonacids. The rosin acids resemble those of commercial rosin, the fatty acids are mostly oleic and linoleic like the fatty acids of soybean oil.

The properties of fatty and rosin acids vary considerably with the kind of pinewood used and with the details of wood handling operations. Whole tall oils ranging in rosin acids from 35 to over 55%, in fatty acids from 60 to 35%, and in sterols, etc., from 5 to 10% are to be found."

Although hardwoods are a major component of the southern forests, the substantial stands of pinewood in the southern states of the United States was the attraction of the pulp and paper industry to locate numerous plants to produce sulfate pulp and its conversion to paper and board.

Likewise, several producers of dissolving-type pulp (viscose and rayon grades) have also located in the southern states and use substantial cords of pinewood in the production of those types of pulp.

It would, therefore, follow that the production of crude tall oil would originate where ever these pulp mills were located and be followed thereafter by the erection of a number of distillation and fractionation plants to crack the crude tall oil into its several components, i.e., tall oil rosin, tall oil fatty acids (of various rosin acid content), distilled tall, tall oil pitch, and tall oil heads.

Statistics are always difficult to use currently because of the time lag and likewise the many revisions that are usually made by the different agencies. For this purpose, the current statistics are less important than what the industry projects for the future so that some estimate can be made of the product in which this group is primarily interested, i.e., rosin.

For this purpose the following sources of information are indicated:

1. Bureau of Census, U. S. Department of Commerce.
2. Pulp Chemicals Association, New York City. An organization made up of a number of producers of tall oil and also producers who are nonmembers, but who furnish statistical data in return for reciprocal arrangements.
3. U. S. Pulp Producers Association, Inc., New York City. An organization that gathers and distributes information on all grades of pulp.

Joseph M. Wafer, West Virginia Pulp and Paper Co., New York, N. Y.

Since we are talking primarily about sulfate pulp paper grades produced in the southern states of the United States, the following information will be of interest as an indication of the operating rate of capacity in the various calendar years:

1947	96.3%
1950	98.8%
1953	96.4%
1956	98.7%
1957	88.3%
1958	80.2%
1959	92.4%—estimate based on first 6 month's production

Table I shows that in the calendar year 1958 the U. S. Pulp Producers Association reported the production of sulfate pulp from pine (paper grades) in the amount of 9,203,726 tons (in southern states).

Projected at rates of 70 to 90 lb. of crude tall oil per ton of pulp would provide 322,130 to 414,168 tons of crude tall oil. In turn, assuming that sufficient fractionation capacity would be available and again assuming that a yield of 35% of tall oil rosin would have been possible, that quantity of crude tall oil would have provided tall oil rosin in the amount of 112,746 to 144,959 tons. In the language used by your group, it would have provided a source of 433,637 to 557,535 drums of 520 lb. each.

To this potential would be added the amount of crude tall oil that is produced as a result of using pinewood in the production of the so-called rayon and viscose type pulps. No individual figures are published on this, but potentially there is probably at least 30,000 tons of crude tall oil annually available from that industry.

Actually, in terms of crude tall oil, Pulp Chemicals Association reported for the calendar year, 1958, a production by its members and purchases from nonmembers totaling 331,612 tons of crude tall oil. Again, assuming a yield on the average of 35% it would have furnished a source of tall oil rosin equivalent to 116,064 tons or 446,400 drums of 520 lb. each.

Actually, the reports issued by the Department of Agriculture indicate that for the full calendar year, 1958, a production of tall oil rosin equal to 73,682 tons or 283,400 drums of 520 lb. each. We should recognize, however, that there are rosin fractions being taken off these distillation streams that are interchangeably used against gum rosin, wood rosin, and tall oil rosin. However, because of the specifications contained in the revised Naval Stores Act, these fractions cannot be qualified as tall oil rosin, and consequently not reported in any production figures. To that extent, the figures are somewhat misleading as to the actual production of tall oil rosin if we wish to consider interchangeability.

Ernest Holdman, a veteran of the naval stores industry, and currently consultant for Heyden Newport

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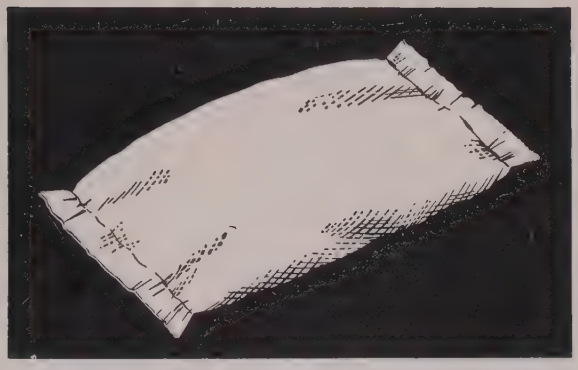

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Table I

Production in southern states U.S.A. paper grades sulfate pulp from pine—U. S. Pulp Producers Association, cal. year 1958, tons	Projected C.T.O. yields per ton of pine pulp, lb.	Potential C.T.O. production if all tall oil skimmings acidified, tons	Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons	Tall oil rosin equivalent to drums of 520 lb. each	C.T.O. production & purchases, 1958 Pulp Chem. Association, tons	Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons	Tall oil rosin equivalent to drums of 520 lb. each	Actual production reported by Dept. Agri. Drums of 520 lb. each, cal. year, 1958
9,203,726	70	322,130	112,746	433,637	331,612	116,064	446,400	283,400 drums = 73,682 tons
	75	345,139	120,799	464,612				
	80	368,149	128,852	495,585				
	85	391,158	136,905	526,558				
	90	414,168	144,959	557,535				

The potential crude tall oil production does not envision any crude tall oil availability from grades of dissolving pulp made from pinewood. However, actual production reported to Pulp Chemicals Association undoubtedly includes crude tall oil made from skimmings obtained in the production of dissolving grades of pulp (rayon pulp) where pinewood is used.

Chemical Corp., has for many years compiled naval stores data covering production, disposition, etc., of rosin and turpentine.

Using some of these figures over a 50-yr. period, we quote production data for gum and wood rosin, and more recently, tall oil rosin.

We have arbitrarily selected four periods for each of the naval stores years ending March 31, 1909, 1939, 1949, and 1959.

Naval stores year ending March 31	Gum, drums[a]	Wood, drums	Total, drums	Added production of tall oil rosin, drums
1909	1,998,400	...	1,998,400	...
1939	1,466,344	610,330	2,076,674	...
1949	921,220	1,154,890	2,076,110	...
1959	369,350	1,182,620	1,551,970	305,060

[a] All drums, 520 lb. each.

Including the production of tall oil rosin in the Naval Stores year ending March 31, 1959, we arrive at a total of 1,857,030 drums, which compares with the production of 1,998,400 drums of rosin produced 50 years ago which at that time all consisted of gum rosin. To those of us who are engaged in the chemical industry, we would certainly have to reach the conclusion that very little progress production-wise has been made in this 50-yr. period except to the credit of the wood naval stores segment, that they were able to fill the gap left by the constant decline in gum rosin production.

This same veteran, Ernest Holdman, has publicly stated on numerous occasions that the supply of stumps in economic locations may likewise adversely affect the future production of wood rosin, and to that extent declines may be expected according to him in the not too distant future.

The constant decline in gum rosin production over the years and the indications of a similar situation developing on wood rosin production would lead one to believe that the entrance into the tall oil production field by large factors in the naval stores industry was in anticipation of the opportunities offered to them of an alternative source of supply of rosin.

Such companies would include Hercules Powder, Heyden Newport Chemical Corp., Monsanto-Emery, Glidden Co., Crosby Chemical Co., and Arizona Chemical Co. The latter company is a jointly owned enterprise involving American Cyanamid Co. and the In-

Table II

Production in southern states U.S.A. paper grades sulfate pulp from pine—U. S. Pulp Producers Association, 6 months 1/1/59 to 7/1/59, tons	Projected C.T.O. yields per ton of pine pulp, lb.	Potential C.T.O. production if all tall oil skimmings acidified, tons	Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons	Tall oil rosin equivalent to drums of 520 lb. each	C.T.O. production & purchases, 6 mos. 1959 Pulp Chem. Association, tons	Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons	Tall oil rosin equivalent to drums of 520 lb. each	Actual production reported by Dept. Agri. Drums of 520 lb. each—6 mo. 1959
5,209,933	70	182,347	63,821	245,465	205,393	71,887	276,488	178,160 drums = 46,322 tons
	75	195,372	68,380	263,000				
	80	208,397	72,939	280,535				
	85	221,422	77,498	298,069				
	90	234,447	82,056	315,600				

The potential for the full calendar year, 1959, at the above rate is projected as follows:

Southern states U.S.A. paper grades sulfate pulp from pine—U. S. Pulp Producers Association—projection for full cal. year 1959, tons	Projected C.T.O. yields per ton of pine pulp, lb.	Potential C.T.O. production if all tall oil skimmings acidified, tons	Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons	Tall oil rosin equivalent to drums of 520 lb. each	C.T.O. production & purchases projection 1959 cal. yr. Pulp Chem. Association, tons	Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons	Tall oil rosin equivalent to drums of 520 lb. each	Actual production reported by Dept. Agri. Drums of 520 lb. each, cal. year 1959
10,419,966	70	364,694	127,643	490,935	410,786	143,775	552,976	...
	75	390,744	136,760	526,000				
	80	416,794	145,878	561,069				
	85	442,844	154,995	596,135				
	90	468,894	164,113	631,204				

The potential crude tall oil production does not envision any crude tall oil availability from grades of dissolving pulp made from pinewood. However, actual production reported to Pulp Chemicals undoubtedly includes crude tall oil made from skimmings obtained in the production of dissolving grades of pulp (rayon pulp) where pinewood is utilized.

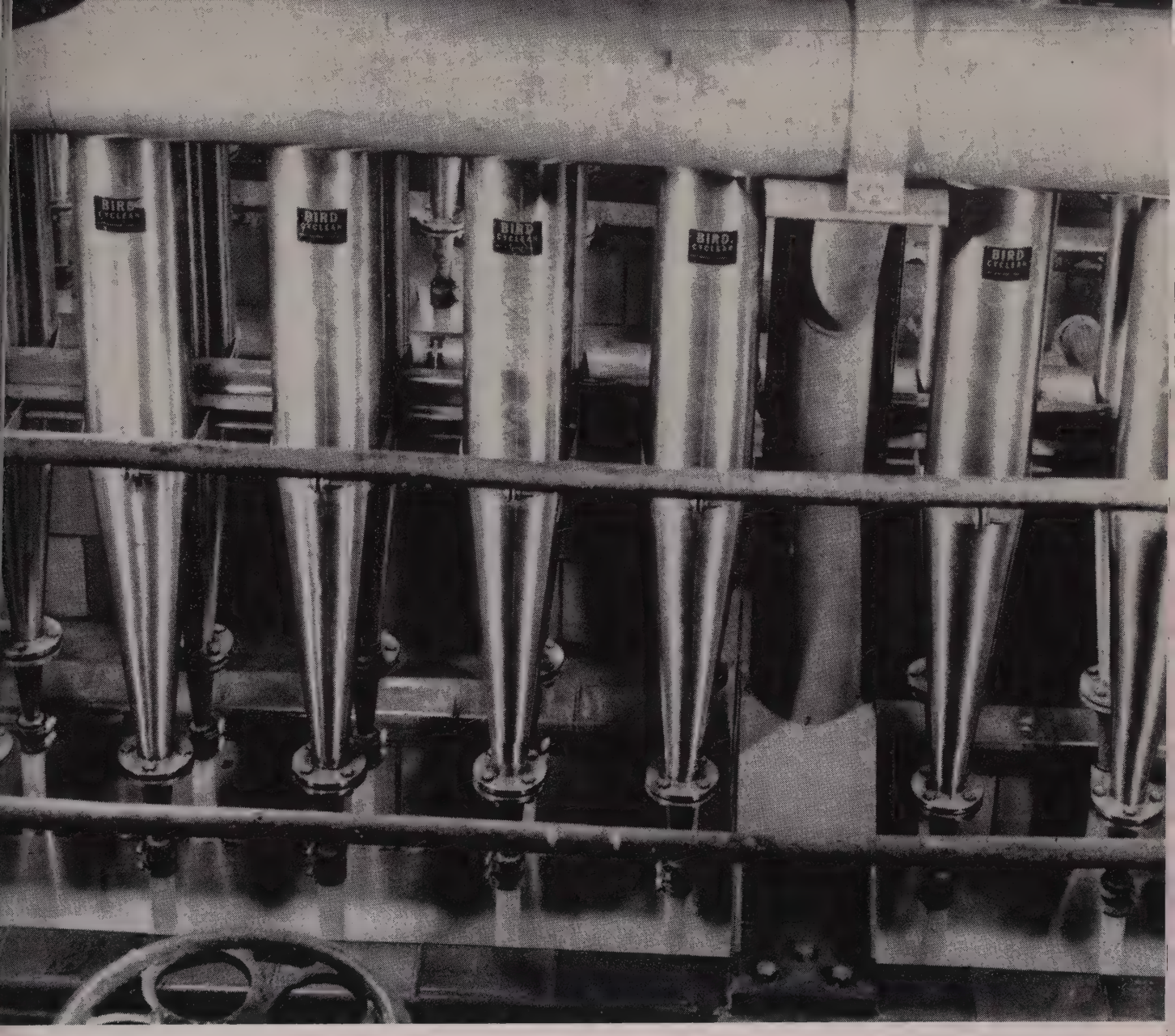

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Table III. Production Data—Gum, Wood, and Tall Oil Rosin for Naval Stores Years Ending March 31, 1909, 1939, 1949, and 1959

Naval stores year ending March 31	*Gum, drums*	*Wood, drums*	*Total, drums*	*Added production of tall oil rosin, drums*
1909	1,998,400	...	1,998,400	...
1939	1,466,344	610,330	2,076,674	...
1949	921,220	1,154,812	2,076,110	...
1959	369,350	1,182,620	1,551,970	305,060

Southern states U.S.A. paper grades sulfate pulp from pine—U. S. Pulp Producers Association capacity—1960, tons	*Projected C.T.O. yields per ton of pine pulp, lb.*	*Potential C.T.O. production if all tall oil skimmings acidified, tons*	*Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons*	*Tall oil rosin equivalent to drums of 520 lb. each*	*Southern states, estimate of sulfate pulp production (paper grades) (from pine) required '65 based on "Pulp, Paper and Board Supply Demand," tons*	*Projected C.T.O. yields per ton of lb. pine pulp, lb.*	*Potential C.T.O. production if all tall oil skimmings acidified, tons*	*Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons*	*Tall oil rosin equivalent to drums of 520 lbs. each*
11,566,685	70	404,833	141,692	544,970	13,596,000	70	475,860	166,551	640,581
	75	433,750	151,813	585,896		75	509,850	178,448	686,338
	80	462,667	161,933	622,819		80	543,840	190,344	732,092
	85	491,584	172,054	661,746		85	577,830	202,241	777,850
	90	520,500	182,175	700,673		90	611,820	214,137	823,604

ternational Paper Co. American Cyanamid is a large factor in the production of rosin size and International Paper, of course, is a large consumer.

Let us review, then, what is currently taking place in the tall oil industry to see to what extent tall oil rosin availability from this industry might help to fill the gap represented by the constant decline in gum rosin production, and to what extent it might supplement the further losses that may be involved with wood rosin production.

For this purpose, we also reproduce Table II which gives the following information:

Production of sulfate pulp (paper grades) from pinewood in the south for the first 6 months of the calendar year, 1959, as reported by the U. S. Pulp Producers Association, totaled 5,209,933 tons.

Again assuming yields of 70 to 90 lb. of crude tall oil per ton of pine pulp, it offered a potential source of crude tall oil to the extent of 182,347 to 234,447 tons.

Again assuming adequate fractionation capacity and again assuming a yield of 35% of tall oil rosin, that quantity of crude tall oil would have provided a source of 63,821 to 82,056 tons of tall oil rosin, or the equivalent of 245,465 to 315,600 drums of 520 lb. each.

Production of crude tall oil and purchases from nonmember companies as reported to the Pulp Chemicals Association for the first 6 months of the calendar year, 1959, totaled 205, 393 tons of crude tall oil.

Assuming a potential yield of 35% of rosin, this would have provided a source of 71,887 tons or 276,488 drums of 520 lb. each.

The actual production of tall oil rosin for that 6-month period, as reported by the Department of Agriculture, totaled 46,322 tons, equivalent to 178,160 drums of 520 lb. each.

Again, the same comment must be made that there are rosin fractions coming off these distillation streams that for many purposes are interchangeable with gum, wood, or tall oil rosin. However, since they cannot qualify as tall oil rosin, no production figures are reported. To that extent, these figures are again misleading if we are thinking in terms of interchangeability or replacement.

Again, on the potential availability of crude tall oil, we do not take into consideration the amount of crude tall oil that becomes available from the production of rayon and viscose-type pulps where ever pinewood is used.

Projecting crude tall oil production for calendar year, 1959, and again in the same category, we would come up with a potential tall oil rosin equivalent of 552,976 drums of 520 lb. each. However, if we conclude that the actual production will be double that of the first 6 months, then for the full calendar year of 1959 the tall oil rosin production would reach 356,320 drums. Again, the potential crude tall oil availability would be

Table IV

Crop years, 1929–57 (begin October 1)	*Year*	*Soya bean average price received by farmers per bushel*	*Year*	*Prices on crude soya bean oil, cents per pound in tankcars at midwestern mills*	*Year*	*Prices U. S. soya bean oil meal—average price per ton bags in carlots Chicago*
Crop Years 1929–38						
	1929–30	High $1.88	1929–30	High 9.1	1929–30	High $50.40
Seasons price average	1931–32	Low 0.50	1931–32	Low 3.4	1938–39	Low $26...
Ten-year lowest	1932–33	0.44	1932–33	2.9		
Ten-year highest	1929–30	2.11	1929–30	10.7		
Crop Years 1939–48						
	1947–48	High $3.33	1947–48	High 23.8	1947–48	High $91.60
Seasons price average	1939–40	Low 0.81	1939–48	Low 4.9	1939–40	Low 28.90
Ten-year lowest	1939–40	0.67	1939–40	3.9		
Ten-year highest	1947–48	4.11	1946–47	33.6		
Crop Years 1949–57						
	1951–52	High $2.73	1950–51	High 17.8	1951–52	High $96.25
Seasons price average	1957–58	Low 2.08	1957–58	Low 10.8	1956–57	Low 58.85
Ten-year lowest	1949–50	1.95	1951–52	9.1		
Ten-year highest	1950–51	3.12	1950–51	20.6		

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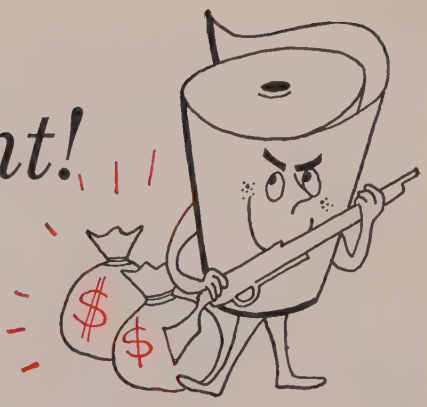

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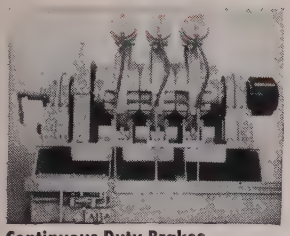

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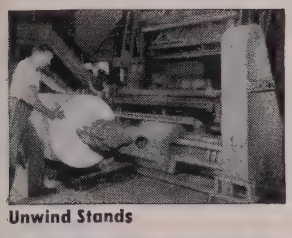

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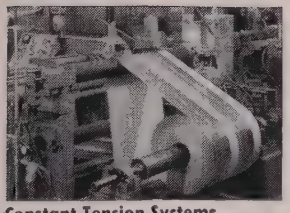

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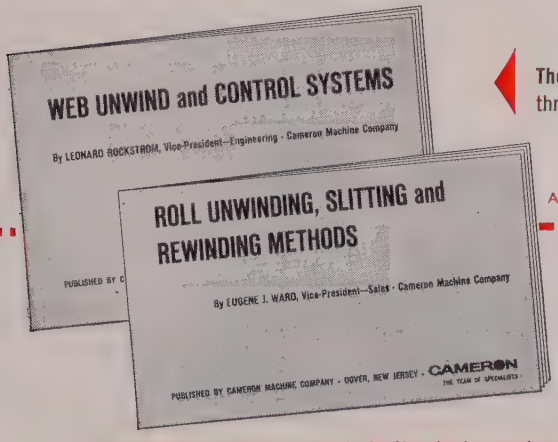
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enhanced by the quantity that is available from the production of rayon and viscose pulps wherever pinewood is used.

Considering that the production of gum rosin for the naval stores year ending March 31, 1959, totaled 369,350 drums of 520 lb. each, and again taking into consideration that year by year there has been a constant decline in the production of gum rosin, we may see for the first time that for the naval stores year ending March 31, 1960, that tall oil rosin production may surpass gum rosin production.

By following the same pattern as in the previous tables, we will project the potential tall oil rosin that may be coming out of the industry.

The U. S. Pulp Producers Association indicate that the capacity in the southern states for the production of paper grades of sulfate pulp for 1960 is 12,399,948 tons. Based on the relative growth over the years of sulfate pulp made from hardwoods and softwoods, they arrived at an estimate as follows:

Hardwood pulp capacity (sulfate).....	833,263 tons
Softwood pulp capacity (sulfate).....	11,566,685 tons

Let us assume for the purpose of developing potential that the pulp mills in 1960 would operate at 100% of capacity, and since we are discussing pine pulp, obviously we will use only that segment intended, i.e., 11,566,685 tons. We then arrive at the following potential:

The Department of Commerce recently revised a report dated June 17, 1957, and resubmitted a further report on July 15, 1959, to the Congressional Committee

Southern states U.S.A. paper grades sulfate pulp from pine—U. S. Pulp Producers Association capacity—1960, tons	*Projected C.T.O.,[a] yields per ton of pine pulp, lb.*	*Potential C.T.O. production if all tall oil skimmings acidified, tons*	*Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons*	*Tall oil rosin equivalent to drums of 520 lb. each*
11,566,685	70	404,833	141,692	544,970
	75	433,750	151,813	583,896
	80	462,667	161,933	622,819
	85	491,584	172,054	661,746
	90	520,500	182,175	700,673

[a] C.T.O. = crude tall oil.

on Domestic and Foreign Commerce. This report is entitled, "Pulp, Paper and Board Supply Demand—Newsprint Outlook . . . 1959."

This report estimates that in 1965 there will be required production in the United States of 43,800,000 tons of paper and board. Your speaker requested the secretary of the U. S. Pulp Producers Association to see whether a further interpretation of this report could be made. This would be needed in order to get some estimate on my part of what 1965 would require in terms of sulfate pulp (paper grades) originating in the southern states.

Many assumptions had to be made, but the secretary concluded on an historical basis that in 1965 there would be required a production in the United States of 17,800,000 tons of sulfate pulp. Historically, the southern area has accounted for approximately 82% of the production of sulfate pulp (paper grades), so on that assumption, the conclusion reached was that in 1965 based on this government report, there would be required production in the southern area of 14,596,000 tons of sulfate pulp (paper grades).

Your speaker then translated these figures to the basis that in terms of softwood pulp (paper grades) this would mean a required production in the south of 13,596,000 tons, and leaving 1,000,000 tons of sulfate pulp to be made from hardwoods.

Again, utilizing this figure of 13,596,000 tons as required production in 1965, we could then reach the following conclusions:

Southern states, estimate of sulfate pulp production (paper grades) (from pine) required in '65 based on "Pulp, Paper and Board Supply Demand," tons	*Projected C.T.O. yields per ton of pine pulp, lb.*	*Potential C.T.O. production if all tall oil skimmings acidified, tons*	*Potential tall oil rosin in C.T.O. at yield of 35% if sufficient fractionation capacity available, tons*	*Tall oil rosin equivalent to drums of 520 lb. each*
13,596,000	70	475,860	166,551	640,581
	75	509,850	178,448	686,338
	80	543,840	190,344	732,092
	85	577,830	202,241	777,850
	90	611,820	214,137	823,604

Although the pulp and paper industry has been running at a high rate of production during the present year, there are still indications that the present capacity will not be fully utilized until somewhere around 1960. If this estimate is finalized, then the figures reported by the government as being required in 1965 may be pushed back further. For the first 6 months of the calendar year 1959 production of paperboard in the United States

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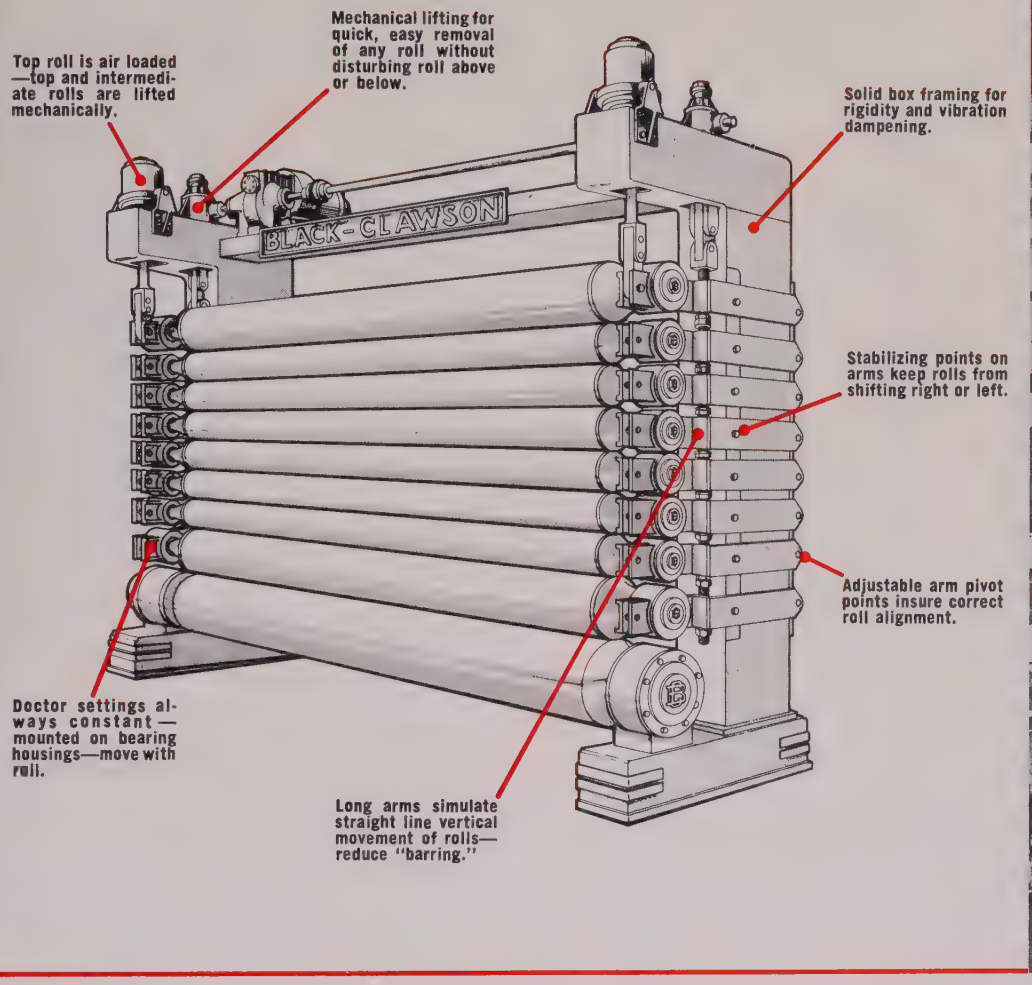
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Pulp and paper division

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totaled 17 million tons—up 13.6% over same period 1958 and 5% high than first 6 months calendar year 1956.

Ernest Holdman indicates that for the Naval Stores year ending March 31, 1959, the production of wood rosin amounted to 1,182,620 drums of 520 lb. each. In effect, this would mean the equivalent of 307,481 tons.

To provide 307,481 tons of tall oil rosin, the amount of crude tall oil availability would have to total 878,517 tons. This is based on a yield of 35% of tall oil rosin, and again the assumption that fractionation and distillation equipment would so provide.

Now, translating this back in terms of pulp, and utilizing a yield of 90 lb. of crude tall oil per ton of pine pulp, it would be necessary to produce 19,522,711 tons of sulfate pulp (paper grades) utilizing pine as the source.

While the pulp and paper industry has continued to expand, it is not likely that we will see a production such as that for some considerable period, so your speaker would have to conclude that the tall oil industry, for a great many years to come, will be unable to replace the production of wood rosin as reported for the Naval Stores year ending March 31, 1959.

To what extent there may be further increases in the utilization of hardwood for the production of sulfate pulp would likewise have adverse affects on the potential crude tall oil availability in the future.

Your speaker again is forced to use some of the statements of Ernest Holdman, consultant to Heyden Newport, to the extent that possibly gum rosin production may take on a new lease on life, or the country may be forced either to import rosin or certainly decrease its exports to those countries that can be supplied with rosin from other world sources.

Otherwise, one would have to reach the further conclusion that other products would have to be substituted for rosin for the many new uses now involved.

The incentive to increase production of tall oil rosin is the market already available by the declining production of gum rosin and some indications of a lesser production of wood rosin.

The rosin acids available in crude tall oil potential production indicates currently that there is insufficient fractionation capacity to take full advantage of these opportunities. This situation will certainly be remedied, as there has recently been an announcement of new fractionation unit to be installed in Louisiana with a put through of a minimum of 40,000 tons of crude tall oil annually. Two other expansions have also been indicated that will probably have a further need of approximately 25,000 tons of crude tall oil per year.

The economics would indicate that there will be more price strength in the foreseeable future in the rosin fractions of tall oil than in the distilled or fatty acids, except where specialty products may be involved.

The upward price movement announced for the fourth quarter of 1959 on wood rosin of 90¢ per 100 lb. and further price increases on light grades of rosin size for the same period follows a previous decline in the price structure of distilled tall oil and fatty acids due to competitive conditions in the price of soya bean oil with which it competes in the protective coating industry.

We have shown in Table II that the production of crude tall oil for the first 6 months of the calendar year, 1959, and projected at the same rate for the full calendar year would have a potential of 552,976 drums, although the actual production may only reach 356,320 drums if it followed the actual production pattern for the first 6 months of 1959 (tall oil rosin).

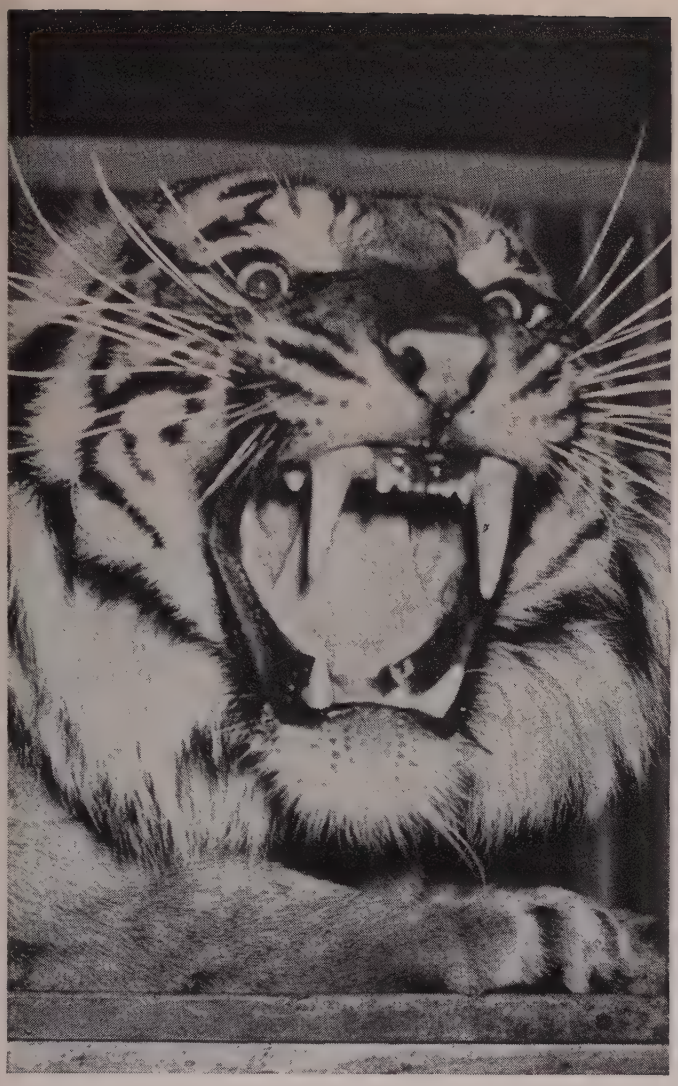
These number of drums coming out of the tall oil industry potentially would be just about enough to provide for the equivalent of the rosin needed in terms of rosin size for the paper industry, for in the naval stores year ending March 31, 1959, government figures indicated that the paper industry consumed 546,266 drums.

There must also be taken into consideration that with the modern equipment installed at these tall oil fractionation plants that the color standards of tall oil rosin in many cases are such that they cannot be graded on the American Rosin Scale. This conventionally could mean that most of the light grades of rosin size in the future will look toward the utilization of tall oil rosin.

The protective coating industry has always been a substantial consumer of tall oil products made possible by good quality products coming out of the industry, and for a substantially long period, a stable price structure.

In the protective coating industry tall oil fatty acids have made considerable inroads due largely to the wide price fluctuation of soya bean oil with which it competes.

While the price structure of soya bean oil was going up, it made possible substantial applications of tall oil fatty acids because of the economic advantage. How-



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ever, now our industry faces an adverse situation in that the prices of soya bean oil have been moving downward, and to that extent, the tall oil fatty acids may find substantial difficulty at present price levels to cope with that situation.

We provide a table covering the soya bean industry for the crop years beginning October 1, 1929–57. In this table we show the high and low prices for soya bean received by the farmers, the price of crude soya bean oil in tankcars at midwestern mills, and the price of the soya bean oil meal in bags at Chicago.

We break this down into three 10 yr. periods:

Period 1929–38

Soya beans: Low price—44¢ a bushel (crop year: 1932–33)
High price—$2.11 a bushel (crop year: 1929–30)
Soya bean oil: Low price—2.9¢ a pound (crop year: 1932–33)
High price—10.7¢ a pound (crop year: 1929–30)
Soya bean oil meal: Low price—$26.00 a ton (crop year: 1938–39)
High price—$50.40 a ton (crop year: 1929–30)

Period 1939–49

Soya beans: Low price—67¢ a bushel (crop year: 1939–40)
High price—$4.11 a bushel (crop year: 1947–48)
Soya bean oil: Low price—3.9¢ a pound (crop year: 1939–40)
High price—33.6¢ a pound (crop year: 1946–47)
Soya bean oil meal: Low price—$28.90 a ton (crop year: 1939–40)
High price—$91.60 a ton (crop year: 1947–48)

Period 1949–57

Soya beans: Low price—$1.95 a bushel (crop year: 1949–50)
High price—$3.12 a bushel (crop year: 1950–51)
Soya bean oil: Low price—9.1¢ a pound (crop year: 1951–52)
High price—20.6¢ a pound (crop year: 1950–51)
Soya bean oil meal: Low price—$58.85 a ton (crop year: 1956–57)
High price—$96.25 a ton (crop year: 1951–52)

Obviously, erratic price changes on soya bean oil when they are moving upward offer many advantages to the tall oil industry if the intent would be to have stable prices always at low levels, for the industry over the years has done exactly that, and has not attempted to take advantage of the prices involved with other competitive fats and oils. However, it is apparent that when the erratic price structure works in the other direction, that the prices at previous levels are seldom recognized. Therefore, the tall oil industry must learn how to cope with all of these problems, and several of the suggestions by the speaker have already been indicated.

With a bumper crop of soya before us, and the indications that cotton seed oil will sell at lower levels would make it appear that the price structure on soya bean oil may decline further.

Cotton seed oil and soya bean oil compete for interchangeable uses in the edible field, and it would be unreasonable to expect the processors of soya bean oil to lose position.

It appears at this stage that with the naval stores factors in the tall oil industry that the prime effort will be in the direction of the tall oil rosin and that fractionation equipment will be installed to take advantage of all of the tall oil rosin that may be made possible from the production of crude tall oil.

To that extent, unless the tall oil industry can find some unique application for the tall oil fatty acids, it is inconceivable that they can afford to lose their position in the protective coating field.

Therefore, it would appear on the surface that if low prices are going to prevail on soya bean oil over the foreseeable future that our industry must give every consideration to finding disposition of these tall oil fatty acids.

With the crude soya bean oil prices at present levels, there must be added on the cost of refining and freight—largely to the primary markets—of about 2¢ a lb. Against this is the need of adding alcohol either in the form of pentaerythritol or glycerin to make useable the utility of the tall oil fatty acids. In most cases, this averages out about 3¢ a lb. Therefore, if the competition into the protective coating field is against soya bean oil, one can easily measure the price relationship that must exist in order to be competitive.

To meet this price situation, the tall oil industry then must face several alternatives:

1. Obtaining lower price structure on crude tall oil.
2. Securing markets outside of the protective coating field where it may not be subject to the same price competition as from soya.
3. The production of derivatives from the tall oil fatty acid fractions, which may then permit upgrading of the price structure.
4. Finding more available markets for two of the fractions which constitute perhaps 25% of the original crude feed, i.e., tall oil pitch and tall oil heads. Much of these fractions are being burned as fuel perhaps not to exceed $20.00 a ton so that currently, they represent quite a drain on the oil operations.
5. A further alternative is to raise the price of tall oil rosin more nearly to the wood rosin price, particularly where they may be interchangeable say for the production of rosin size. In that area, of course, the paper industry would be paying a higher price in order to get some final benefits.

It is apparent that in previous years the naval stores group had more or less looked upon tall oil rosin as a competitor. From these series of tables which have been put together, it now appears that this group can welcome us as a full ally in order that the total production of all forms of rosin may continue at reasonably high levels in order to protect at least the domestic consumption, and perhaps leaving other world producers to provide for those markets that on the surface may not be provided too long from United States production. (Unless gum rosin production may be revived on a higher level.)

Presented at the Naval Stores Breakfast, National Paint, Varnish and Lacquer Association, held in Atlantic City, N. J., Oct. 21, 1959.

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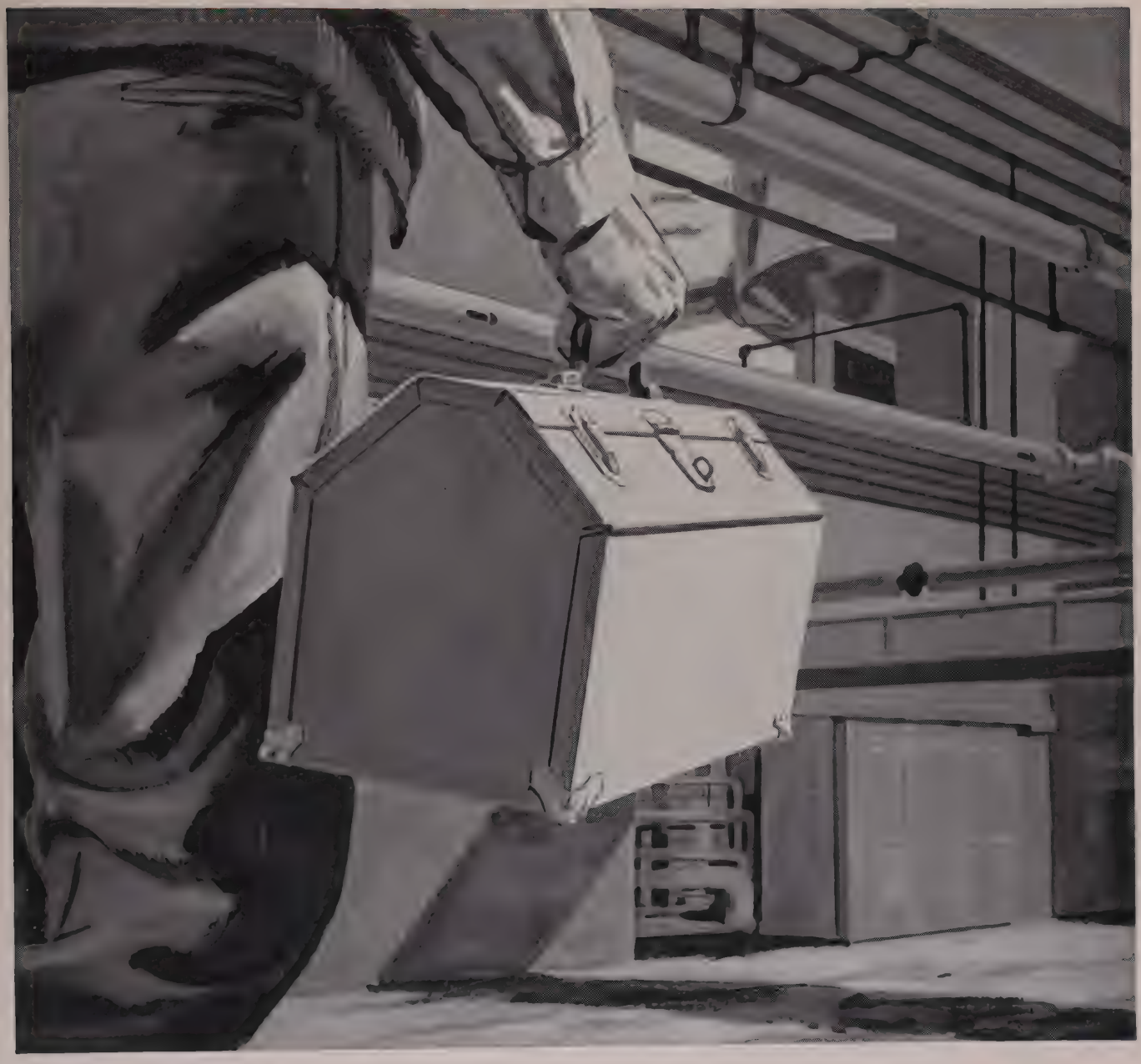

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Up-to-Date Training in Paper Mills

H. WAYNE SMITH

THIS function we call "training" seems to have been misinterpreted and abused so much it has become pretty much of a "bad" word in our industrial language. Possibly we may have been trying to tailor "training programs" to the pattern of our early experiences in "education." Certainly education's place is high on the list of importance, but we seem to have been in a rut in our industrial training approaches somewhere along the line.

We believe a lot of money and time is wasted and, unfortunately, a lot of damage possibly is done to employee relations and overall attitudes by misguided training programs and by those with vague or intangible objectives.

This presentation is not intended as something "brand new" or startling or even "scientific." It is in fact quite the opposite, as I intend to deal only with realities and do what I can to put industrial training in proper focus.

My purpose, then, is to present for your consideration some facts and examples of (1) what we feel is a realistic approach in determining manpower development requirements and (2) what we do about it. So let's start right out with some facts.

FACTORS INHERENT TO ANY JOB OR POSITION

First, we know attitudes and abilities of the people involved can make or break any operation. Thus, with competition today being what it is, we can agree any job in a pulp or paper mill is important or it should be eliminated. Furthermore, we know that any job contains right things that *must* be done and wrong things that must *not* be done.

This being true, we find each job must have a primary function—a reason for its existence—and contain fundamental tasks which must be performed in a certain manner to discharge this function. If we are to be constructive, then, we need the facts—such as job descriptions—to give us our tasks, hiring specifications, and such on all the jobs.

But, "people are all alike in their tendency to be different," and these "individual differences" in job performances tend to cloud the really basic job fundamentals we are seeking—to go deeper into specific considerations on what makes one man's job performance better or worse than another man's in the same job.

To analyze a job in this manner from a training standpoint, therefore, we catalog job tasks and responsibilities with respect to how each element relates to one of four factors we know are present in any job—in one degree or another.

Briefly, here are the four factors we use: skill, knowledge, reasoning, attitude. We will come back to them later, so just keep them in mind for now.

H. WAYNE SMITH, Training Director, Pulp and Paper Mills, St. Regis Paper Co., Pensacola, Fla.

DETERMINING MANPOWER REQUIREMENTS

Before we can apply any analysis like the above, we have to have facts—not guesswork—on job performance. The only way you can determine exactly what you need is to first determine exactly what you have. And the only place that information is available is right out in the mill, personally observing and talking to the men who actually are performing the jobs. When we do this on shift jobs, all men performing each job are contacted (and shown the rough copy on how the others do it) and for "trade analyses," all mechanics in each craft are contacted. That's a pretty big order but it's worth it, as here is what you gain:

1. A factual and comprehensive job description.
2. A personal acquaintanceship with all the men and a first-hand knowledge of what they do, what they feel causes them most of their problems in trying to do a good job, and what they feel they need to know to do it right.
3. Factual knowledge of differences in shift and/or craft practices, and what needs to be done to develop realistic standards of performance and workable uniformity.
4. An awareness on the part of both hourly and supervisory people when such differences actually exist and are causing many needless problems.
5. General acceptance that your reasoning and planning are based on fact rather than "fancy."

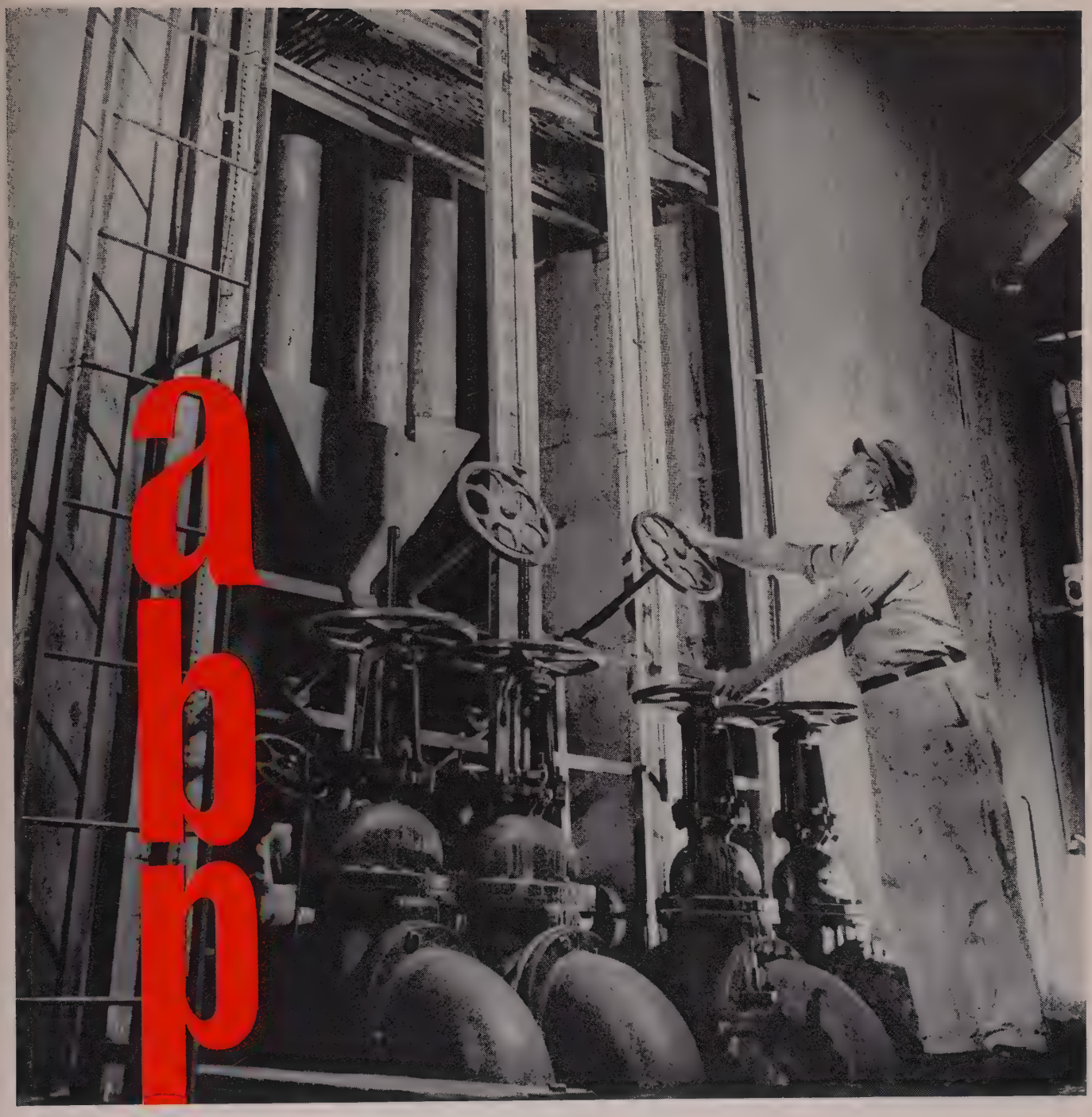
ANALYSIS OF FACTORS

Let's return now to our four factors, as we want to analyze how each of these factors applies to each particular job. So we first have to list the job tasks in a practical sequence (learning or doing). Then we must try to figure out *exactly* what the man needs to know to do it properly and how much or how long he has to "practice" to do it skillfully (develop habits). (As I run through this now, think of yourself and your own job, and see how it applies to *you*, also.)

Here is a sample of about how this type of job analysis would go:

Skill

This can be defined as the control of productive motion and the elimination of nonproductive. With that in mind: What does the man in this position do? Whether he twists knobs and valves or operates machines, handles tools, reads blueprints, or plans for and directs the efforts of others (supervision), he *does something* which requires some degree of skill to do it right. Whether the skills required are physical or mental, he has to practice *doing* them until they become second nature (habit). What are they, and how long will he have to practice if he practices right? What will happen if he practices wrong? What should he practice first so he can be doing that while learning to do the rest?



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For specifications and local offices, see our insert in Chemical Materials Catalog, pages 475-482 and in Chemical Week Buyers Guide, pages 37-44.

Knowledge

Exactly what does he need to know (about the mill, the machines, the men, the practices, policies, procedures, etc.) in order to do whatever needs doing in the correct manner. Does he need to know other people and what they are doing, too? What should he learn first (single-task knowledge) so he can get started? Next? Following that?

Reasoning

There should be a good reason for doing every task a job calls for or the task shouldn't be included. What is the reason for each task (or related grouping of tasks) in this job and how does it fit into the overall "job" reasoning? The intelligent application of adequate skill and knowledge is what we are after—"the right person doing the right thing in the right manner at the right time." Both the "task" and the overall "job" reasoning must be taught; assuming it will be picked up by "experience" costs too much and is too risky. How do you want the man in this job to think constructively about each task he does, his overall job, his security and satisfaction, you, the company? (This must go with the way he learns the what, how, why, and when of each task.)

Attitude

"Going through the motions" might get a man by, but it builds nothing lasting or stable. A man's attitudes about a task or a job or you or a company are built by the manner in which these things relate to his own requirements of self-respect and self-interest. He tends to fit or compare what he sees demonstrated by others around him into the personal attitudes he originally brought to the job. What will he see . . . and hear . . . and feel . . . and need on this job to develop into the stable, mature, trustworthy employee you want?

CLARIFYING OBJECTIVES

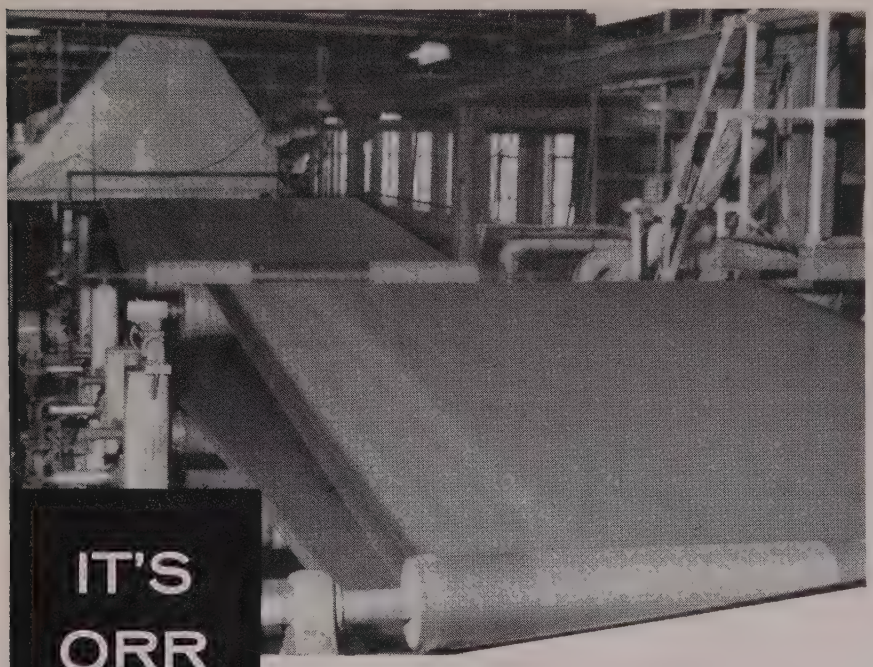
Using job facts in the above manner, we can arrange each job to outline exactly when and what we have to do to accomplish these basic objectives:

1. Develop whatever skill, knowledge, and/or reasoning a man (or a group) needs—to do a job productively—with a minimum of close supervision in the shortest possible period of time.
2. Develop whatever attitudes are necessary so he (or they) will do it productively—when your back is turned.

APPLICATION—GENERAL

Training programs must be tailored to reach a certain goal, which means (when considering the difference in individuals and circumstances) probably no two are identical. Most of ours, however, are planned on this basic premise of attaining maximum productivity in the shortest possible period of time.

We figure the rather common practice, particularly so in operating jobs, of letting the man on a job "break in" the new man to the job tasks—and then let him pick up the rest by "experience" (exposure)—not only is wasteful in actual dollars spent, but the new man picks up some of the



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PUMPAGE

Goulds reports on trends in pulp and paper

PAPER BOOM. While other industries increased production 60% during the past twelve years, the paper industry increased its production by 80%. Two things combine to assure continued gains in production in the decade ahead: new people and new products. This year's population growth is expected to expand the market for paper. And population is expected to grow at an ever-increasing rate, enabling us to reach the 200-million mark by 1967. Another promise for stepped-up sales during the 60's lies in new technology. Paper is entering its scientific age. More and better research will create new products and new markets for old ones. Plastics and aluminum will capture some markets but not as fast as paper opens up others. It all adds up to a favorable balance between capacity and production—probably by next year.

SOBER LOOK AT LIQUOR. Gnawing away at your pumps, liquor loses its appetite when you switch to glass. The Goulds-Pfaudler glassed pump gives the same corrosion resistance you get in a glassed-steel reactor. Its tough, permanently-fused-to-metal glass fights chlorine dioxide's corrosive bite, resists the violent attacks of all concentrated bleaches. If your pump life is short—write us for details on this glassed centrifugal. Ask for Bulletin 725.2

SLEDGE IN A SLURRY. An absent-minded worker left a sledge hammer in a suction pipe at a western mill. Pulled along later by the flow, the hammer hit the pump impeller with a bang. Damage? Naturally—but not what you'd expect. We replaced only the impeller and side plate. The shaft was undamaged. Parts right out of stock. No dismantling of suction or discharge piping. We don't suggest tossing a sledge hammer into your pumpage—but if you do, it's nice to have a Goulds in your system.

OBSERVATIONS

on pumps for the paper industry

by A. W. Woodbury, Assistant Sales Manager, Goulds Pumps

In 1959, 96 per cent of the centrifugal pumps Goulds has applied to the paper industry were post-1950 designs. Reason: For the past ten years our Product Development Program has been heavy on paper.

We in the Sales Department have had to maintain a pace commensurate with this program. This emphasis, plus a 112-year accumulation of know-how, adds up to an experience factor that can be of significant assistance in your pumping applications.

Give us an opportunity to share in your pumping problems. Pumps are our only business—we know our field and chances are we can save you time and money.

Goulds Pumps, Inc., Dept. TA-40, Seneca Falls, N. Y.

GOULDS PUMPS

older one's habits (good, bad, indifferent) and attitudes, and there is no way on earth to tell exactly what has or has not been covered. The other extreme to this is the "planned" program that is vague in its objectives or tries to teach too much: e.g., if you expect an operator to have a chemist's background you should send him to college.

We feel the first step in the application of any "planned" operator training, for instance, should be the same as for any other: get the facts on the jobs arranged in a manner that clearly indicates what the man in each has to *do* and needs to *know* to do it right.

If your objective is to improve or change a man or a group currently on the job, a comparative analysis of what the man or group actually *demonstrates* on the job with respect to what is required should pin-point exactly what needs to be done (in each of your four areas of skill, knowledge, reasoning, attitude). A "formula" on this would read: (SKRA needed) minus (SKRA demonstrated on the job) equals (your development objective).

If your objective is "break-in" training of a new person, or of a currently employed group to a new process or machine, you can proceed as above except you actually are starting with zero (in your formula) for "what is demonstrated on the job," and your objective is to build from 0 to 100% in the shortest possible time consistent with the requirements of *all four factors.*

We believe one more thing is important to reasoning and attitude: at least a general knowledge of what is going on in the rest of the mill and thus how each job fits into the overall production picture as well as in its own immediate function.

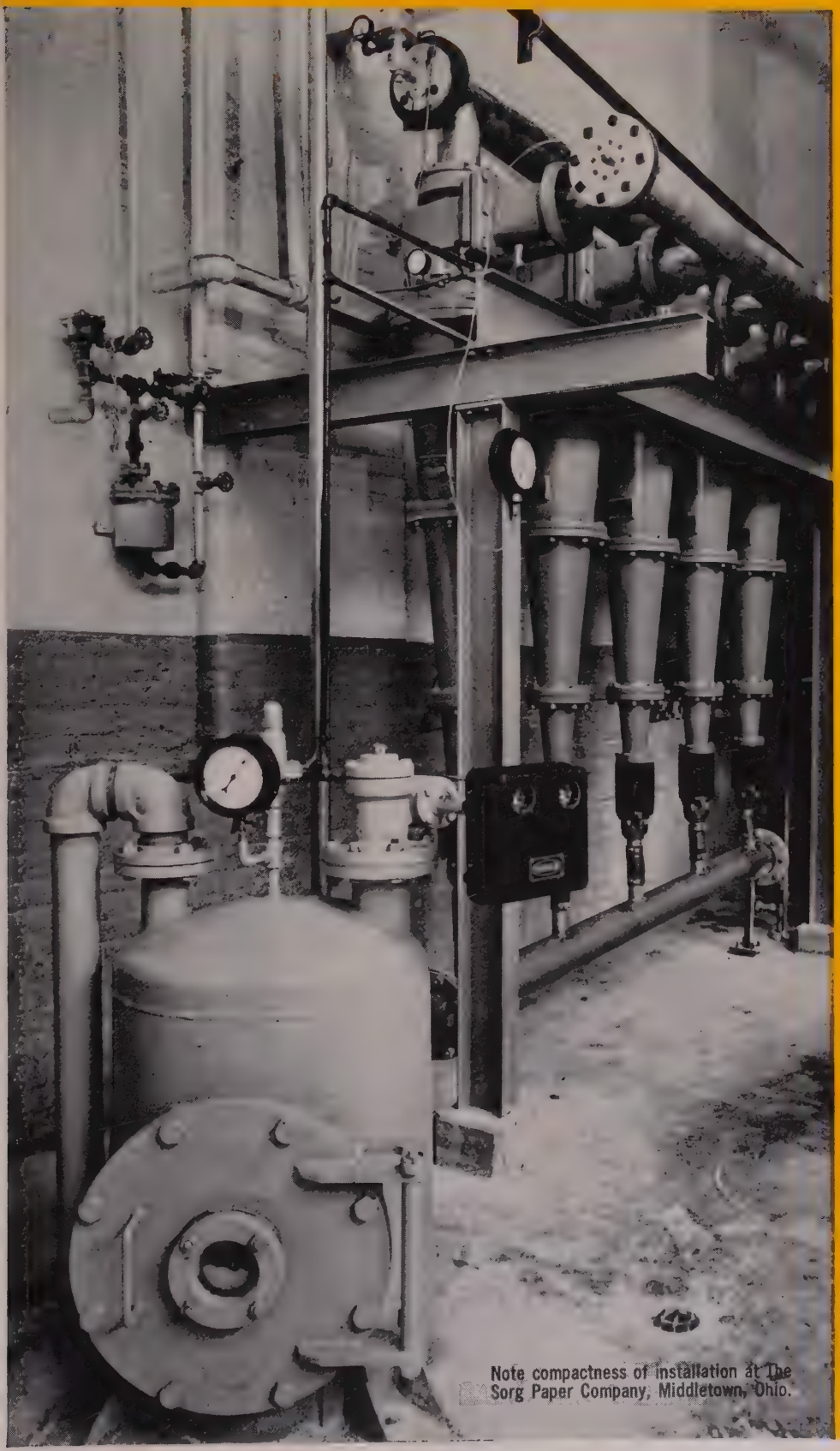
APPLICATION—SPECIFIC

Here we get into what I think is the meat of this whole business —"who does all this stuff and how do you go about it?"

In the first place, if you will forgive a personal reference, we feel we need only a very small training staff because *we* do very little actual teaching, ourselves,

Bauer

Centri-Cleaners with Vacuum Rejects System*



Note compactness of installation at The Sorg Paper Company, Middletown, Ohio.

Eliminate air problems and provide cleaner stock at same time...

From over 100 mills using Bauer Centri-Cleaners equipped with the vacuum rejects system come reports like these:

Cleaner paper . . . improves formation on the wire, since air is kept from entering the cleaners and stock going to headbox . . . compact, neat installation . . . non-plugging . . . requires little if any maintenance . . . less wear . . . less downtime . . . eliminates need for eductors and their high pressure water system . . . reduces need for foam killers...improves quality.

If you want the best value in cleaners, get the details on this Bauer "package."

*U.S. Patents 2,878,934; 2,377,524; and 2,809,567. In Canada, 429,584; 565,199.

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in a "classroom" sense. You can't rate a first-line supervisor properly unless you consider his performance is reflected primarily by what his crew demonstrates on the job. If he is responsible, then, for the quality, quantity, cost, safety, etc. of his crew, it is his job—not ours—to see to it his crew knows what to do and does it productively! In other words, a desirable habit is acquired only through repetition of correct motion over a sufficient period of time for it to *become* habit—the foreman is the only one who can see to it this is done—so, to be effective, the foreman *has* to be the "instructor."

Our job is to see to it he has every bit of help we can give him in *assisting* him to discharge this responsibility.

We can help him by serving as extra eyes, hands, and feet to do what he has neither the time, the impartial objectivity nor, in some cases, the specialized skills necessary to make these job analyses, performance surveys, and to gather other information such as mentioned above.

We can help him by "teaching him how to teach." The biggest part of most operating jobs is—and should be—taught and learned on the job. Most jobs of any responsibility, however, contain certain "things you should know" which are pretty hard, if not almost impossible, to teach on the job due to noise, time, distractions, etc. This portion is what we call "related instruction" and really is easiest to do and accomplishes more when taught off the job.

We can take some of this "related" burden off the foreman's hands by conducting selected parts of this instruction ourselves or by securing for him specialists from other departments such as engineering, technical, etc. An example of this would be for the instrument supervisor to explain to a certain crew how all their instruments work—what they will and will not do, how to use them, what to adjust and what to leave alone, and the like. This ensures that the crew gets the correct information from the right source, and it helps the supervisor keep his instruments

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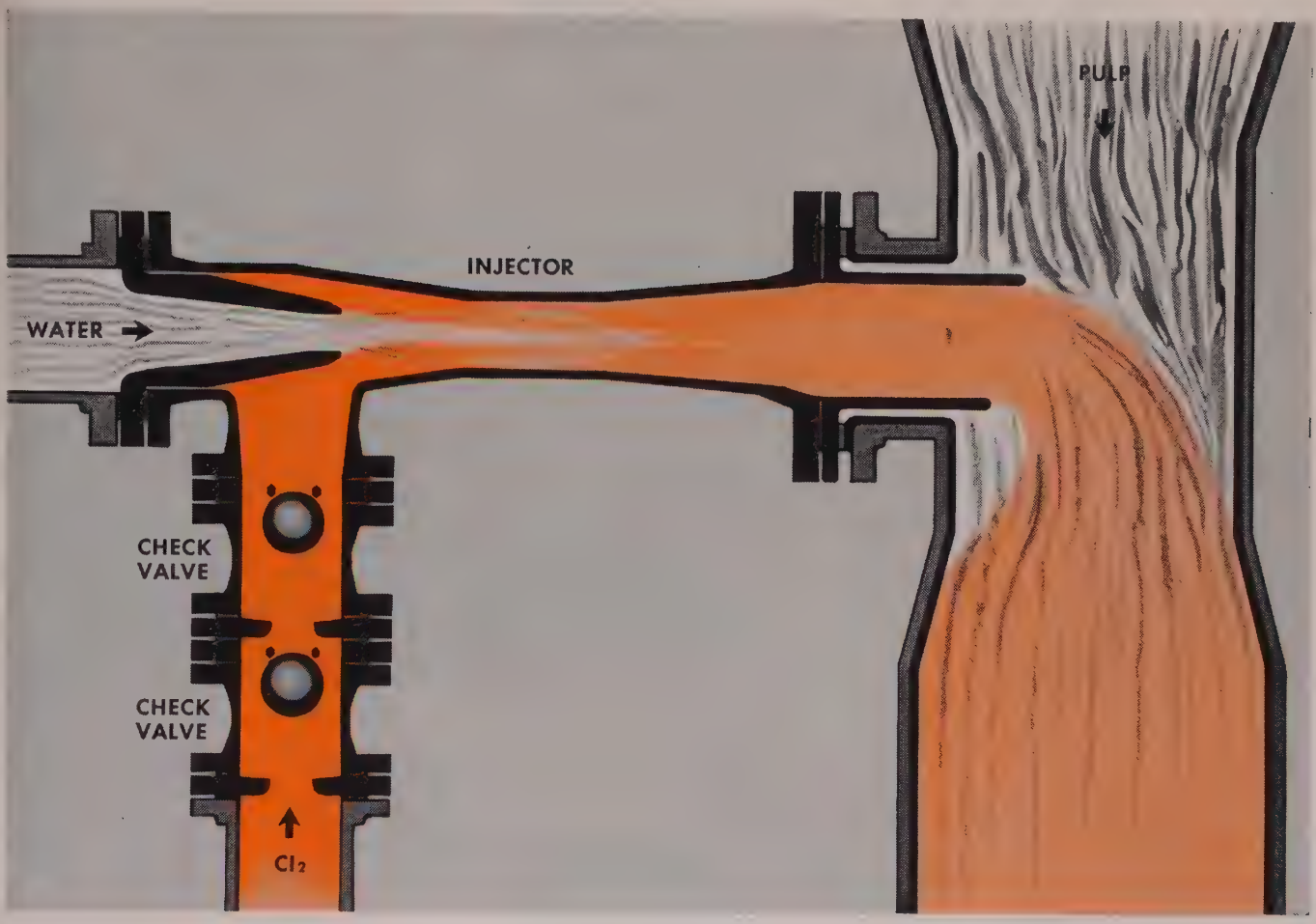

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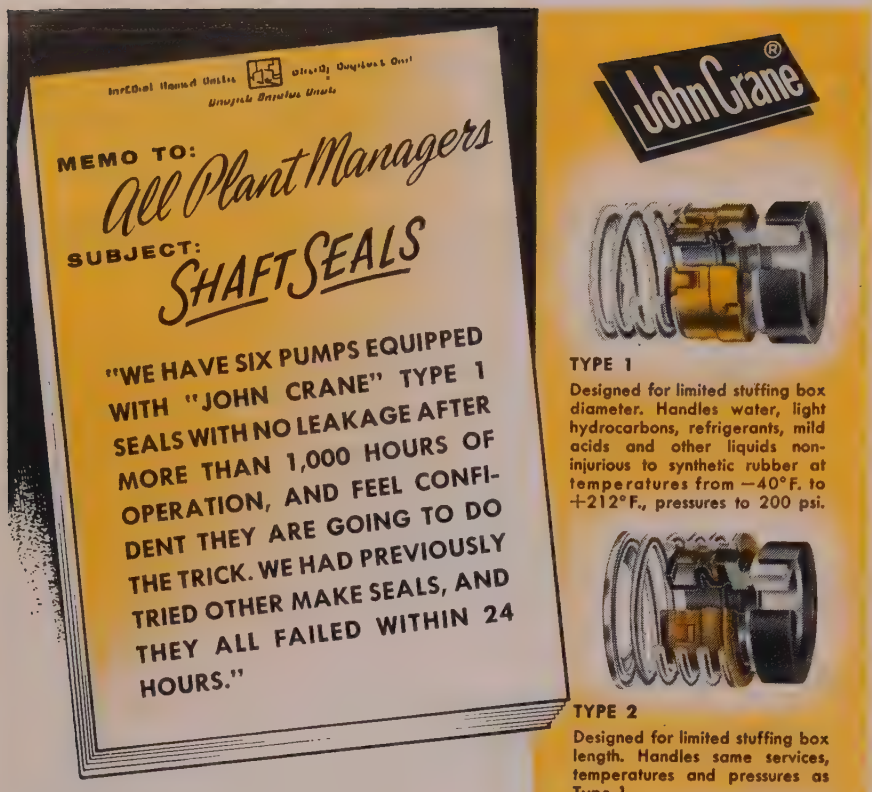
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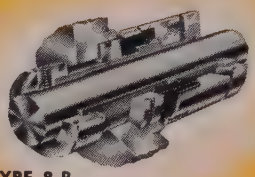

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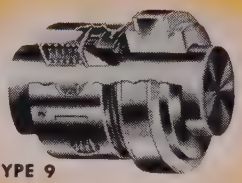

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operating better. That makes it a good deal because it benefits both parties involved in the meeting, so everybody is happy (including the crew foreman).

Meetings of this nature (related instruction) are hard to schedule and present a real problem in both the schedule time and the pay.

We try to hold such meetings to a bare minimum and give preference in scheduling to the wishes of the group involved.

To determine "who pays and how much," I feel it should be on the basis of the objective and who receives the most benefit. It really isn't quite that simple, as any improvement program benefits everyone involved, but this approach at least helps us get to the basic issue.

EXAMPLES OF EXISTING PROGRAMS

A brief discussion at this point on some programs and the reasoning behind their development and application might help bring this type of approach a bit more into focus.

Maintenance—helper (apprentice) training. Objective: to develop a 1st class paper mill mechanic in the shortest possible time. (The "time," in this case, first being considered as the formal 4-year program considered standard by the building trades.)

Here is what we did about this one:

1. The mill was divided into six major "work areas": shop, new erections or modifications (construction), paper mill, pulp mill, power house (and recovery), woodyard, and woodroom.

2. The job tasks were reviewed, regrouping and rearranging sequence as practicable, and the related instruction was confined to exactly what was needed and applicable to the work being performed (e.g., math and science are "reviewed," as such, but detailed instruction on certain areas is reserved for such times as *specific application* is possible, wanted, and needed).

3. "Formal" training time was cut to 36 months and three progressive grades of "mechanic" initiated. (First-class mechanics are not hired "at the gate.")

4. The training committee is composed of the assistant main-

What an

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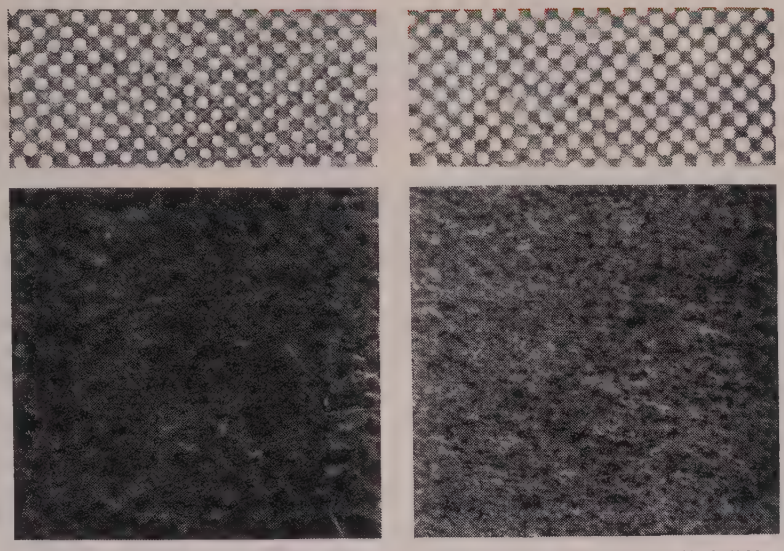

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tenance superintendent, two maintenance area supervisors, two maintenance foremen (the foremen rotate) and is chaired by the training director or his assistant. (By agreement, the Union does not participate physically in these meetings but is always kept fully informed and is consulted on any nonroutine matters.)

5. Classes in related instruction are held on company property after hours of work on the trainee's time. Attendance is voluntary, but all trainees must meet required standards and pass all tests prior to any advancement in classification.

About a year was gained in both time and productivity by these changes, and graduates receive nationally recognized completion certificates because the program is registered and complies with both State and Federal requirements.

The Union men helped set up the program and thus believe in it, so they police the trainees far better than could anyone else. The foremen also helped work out the program and thus realize the development of qualified and dependable mechanics is *their* responsibility—not that of the training department—so we do not get the "lip service" so prevalent in some locations.

A performance report is made out on each trainee monthly by the training department and foremen involved, and discussion on these reports comprises the major portion of the training committee meetings. This report permits pin-pointing the exact degree in all significant areas to which each trainee demonstrates his progress.

I have gone into a little detail on this program because, first, I thought you might be interested in this particular one, and second, as a concrete example of how a crystal-clear objective can guide and control your approach to an industrial training problem.

Here are some other representative examples which may be of interest:

Maintenance-mechanics. "Clinics" on new equipment, materials, methods, standard practices, etc.

Accountants. Familiarization on mill processes and practices, personnel, terminology. Thirteen sessions (one per week) of 3 hr. each.

Engineers and Chemists—new graduates. Turned over to training department for 6 weeks. Familiarization with mill processes and practices, personnel, etc.

Engineers and Chemists—previous paper mill experience. Turned over to training department for from 1 to 6 weeks (dependent upon nature and extent of previous experience): familiarization with practices, equipment, and personnel of this mill.

Instrument Men, Electricians, Lab Personnel (hourly). Mill process and practices, specific applications to individuals and/or jobs involved. Thirteen sessions (one weekly).

Operating Personnel (hourly). As above on process, when requested by department, and special "clinics" as for mechanics.

New Secretary or Clerk. Complete indoctrination into company organization, personnel, policies, practices, forms, duplicating devices and procedures, stores, supplies, etc. (16 hr).

SUMMATION

I have purposely omitted going into a number of areas where training is carried on, preferring rather to use these few examples to illustrate a certain philosophy and approach to industrial training. It must be evident we believe a training department cannot be as efficient as it should be without the complete confidence and respect of all the people it should serve. This, we believe, can only be earned by being objective, factual, and down to earth in approaches and methods.

For industrial usage, to "train" means to "change" or "orient"—not necessarily to "educate"—and our process training for engineers, accountants, and such exemplifies this. So training is not reserved for incompetents, misfits, or the "uneducated." For that matter you alone train your associates, and the people who look to you for guidance and direction, every day of your life; you train them you will accept substandard performance or you train them you will not; you train them what kind of a guy you are and what your intentions are toward them by the way you look, talk, and act as you go about doing whatever it is you do; you train them by demonstrating daily what you know, how you think, your attitude toward yourself, God, and your fellow man.

This is true of everyone in a management or consultive situation. Why, then, do so many of us adopt the attitude that "training" is a job for *someone else*—someone who "goes in for" that sort of thing?

That is why we say no program of training can be very effective—and certainly not lasting—on "lip service" from supervision, either line or staff. And very definitely cannot be effective on lip service from line supervision. A program of pure "education" or strictly personal improvement that is worth while, possibly yes, but not industrial training as we define it.

So, in conclusion, we firmly believe if you have a clear picture of the results you are after, a definite plan and schedule of action, and confine your interests and activities to exactly that which applies directly to job results in terms of "productivity versus time"—you will be up to date in your training.

Presented at the Fourteenth Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

Pulp Bleaching Conference

of the

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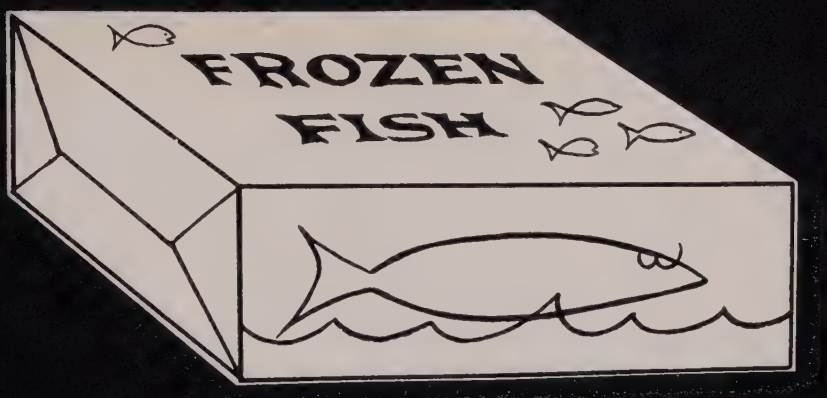

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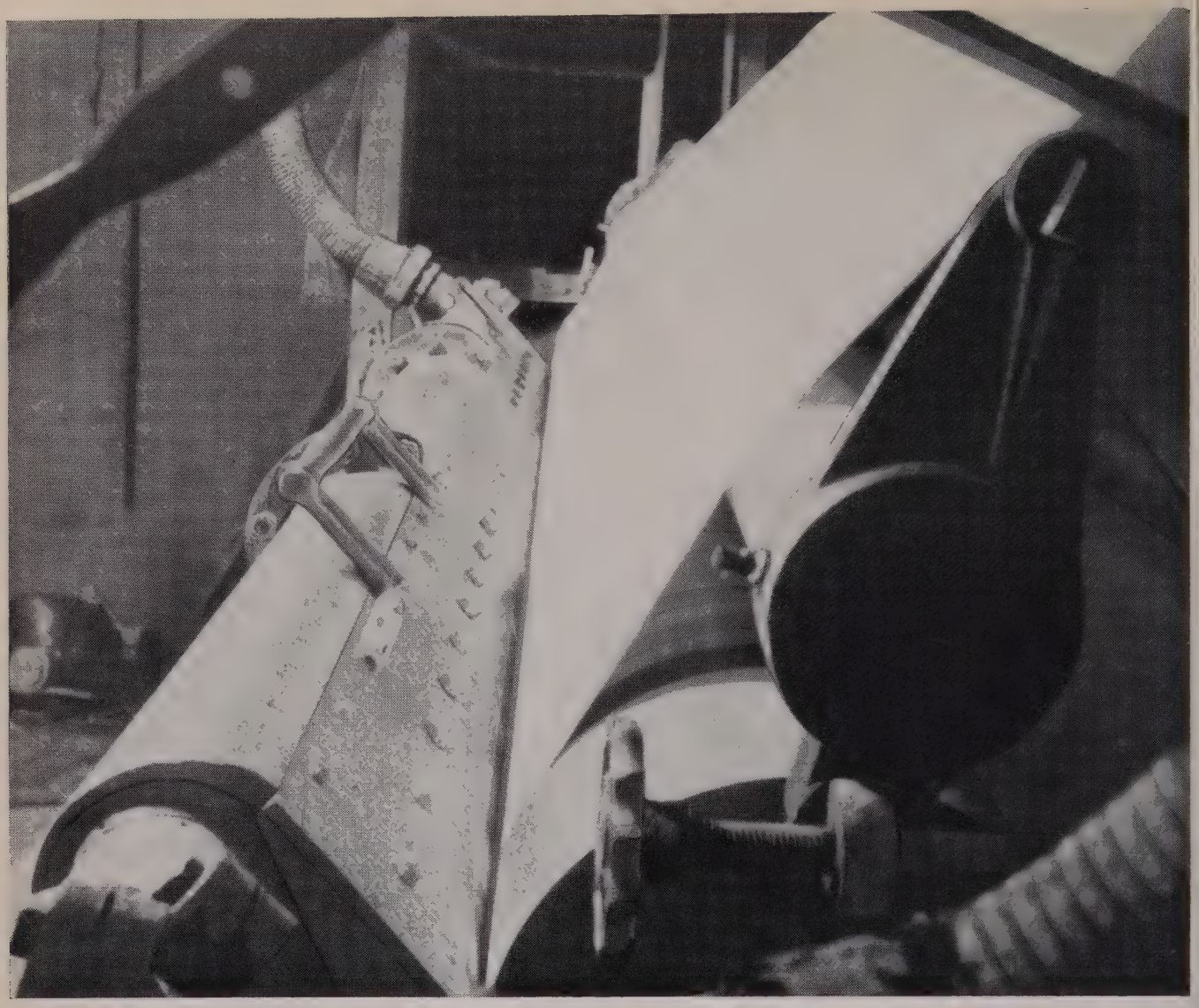

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An American Industry First

Rare Document Proves Papermaker First to Use Chlorine for Bleaching in the United States

SIDNEY M. EDELSTEIN

The rich historical background of the pulp and paper industry in the United States has been held important by relatively few papermakers.

Although we have gone far in a comparatively few years, pride in our heritage can but only help us to realize today's dreams for even greater technological achievements in the future.

It is hoped that this important document will stimulate others to ferret out historical facts from long-forgotten, company-held documents and produce articles for the enlightenment of all.

William H. Chisholm, President,
Oxford Paper Co.

AMERICAN paper manufacturers have often been confronted with the problem of obtaining an adequate and suitable source of fibrous raw materials. A new chemical process has usually been the answer. Most of us think of the introduction of the "sulfite process" as the first example. Actually, it was the adoption of chlorine for bleaching rags which marked the real beginning of the chemical approach to "paper" problems.

While European papermakers had taken up the use of this new chemical bleach almost as soon as its potent action became known, it has generally been claimed that the Americans were at least 40 years late in making use of this discovery.

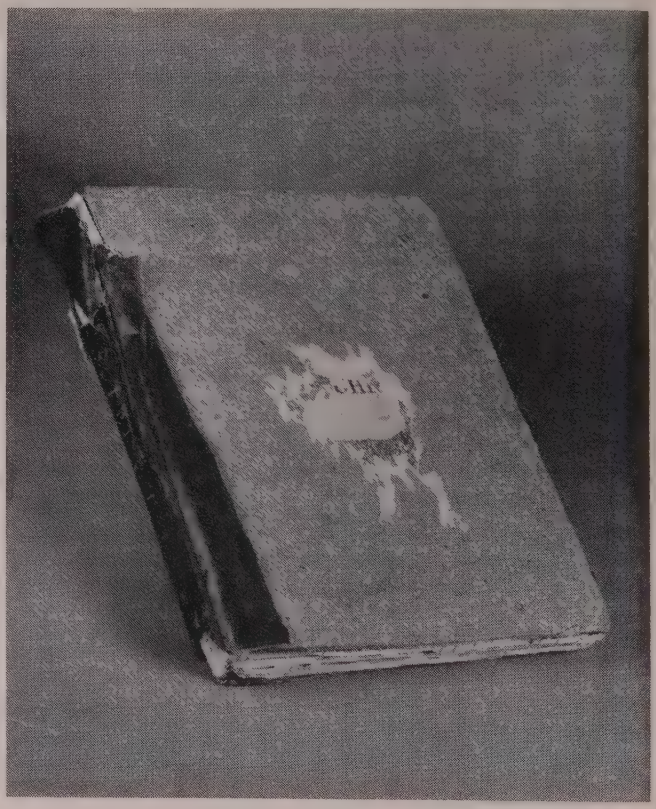
In discussing the raw material problems of early American papermaking, Williams Haynes, the historian of the American chemical industry, had this to say:

"Real relief from the raw materials impasse came about 1830 when chlorine bleaching was introduced. This innovation proved to be analogous in its effects to the solution by this same chemical reagent of the gray goods' problem in the textile industry. Chlorine bleaching enabled papermakers to rework paper stock and also to use soiled and colored rags.

"Unfortunately the record of where and by whom chemical bleaching was first introduced into American paper mills has been lost. To borrow the already well known bleaching technique from the textile industry was an ingenious but not a revolutionary adaptation. It may well have been made independently in a number of different plants. Chemical processes were then heavily veiled in mystery and in accordance with ancient craft habits still in vogue, the early use of chlorine was no doubt cherished as a valuable trade secret. We know definitely that chemical bleaching was employed here (the United States) about 1830 and that it soon became almost universal practice. By that time it became an essential element in pulping both wood and straw and its mechanical application had been much improved" (*1*).

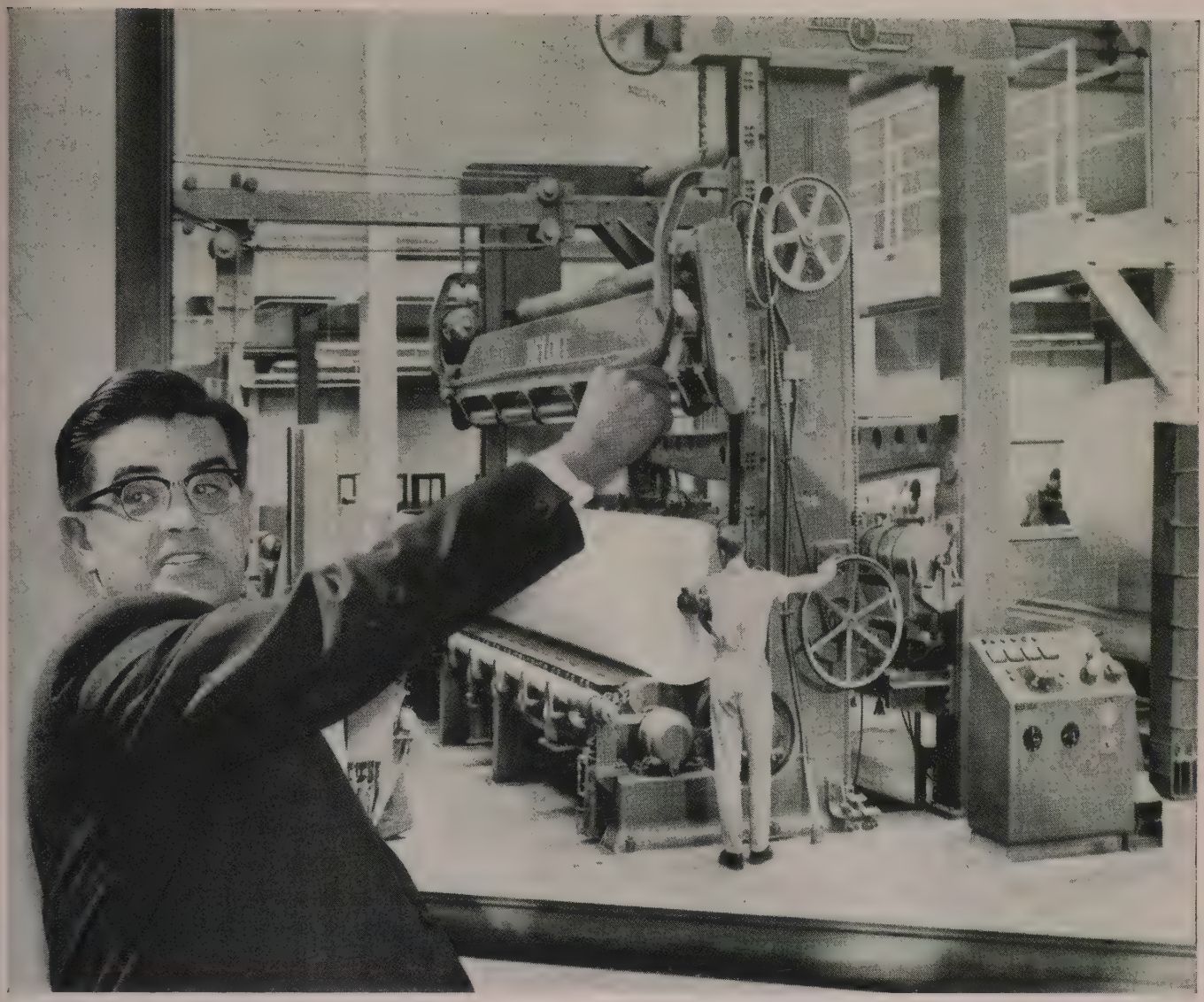
Fortunately, this writer has recently discovered manuscript records of Delaware's first paper mill which completely disprove the claims of American slowness in adopting chlorine to paper manufacture. These records prove that as early as 1798, the use of chlorine for bleaching papermaker's rags and paper was the subject of an American patent and that chlorine was being manufactured and being used for bleaching rags at the Gilpin Paper Mills in Delaware by the summer of 1804. Furthermore, these early dates would indicate that in this country the paper industry was the first to adopt the use of chlorine and not the textile industry as has been suggested by Haynes and others.

The discovered records consist of 179 sheets of old paper of different manufacture, covered with writing in different hands, and bound together. Various parts of the writing, dates inscribed, and other internal evidence, indicate that these are records of the old Gilpin Mills first erected on the Brandywine in Delaware in 1787. Further studies have revealed that a portion of the writings are in the hand of Joshua Gilpin, one of the owners and founders of the Brandywine mill, and are actually technical letters on the use of chlorine for bleaching as practiced in England and Scotland at



The Gilpin manuscript records on bleaching

SIDNEY M. EDELSTEIN, Dexter Chemical Corp., New York, N. Y.



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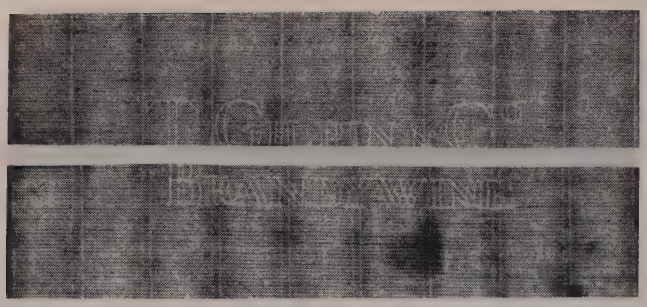


Blank pages from Gilpin records, showing watermarks, "T. Gilpin and Co." and "Brandywine"

the end of the 18th century. They were written by Joshua to his brother, Thomas, in Delaware, during the former's stay in England during the years 1795 to 1801. The records also contain detailed plans of the bleaching room at the Brandywine Paper Mill, details of the equipment in use for making chlorine in 1804, and records of operation. Of equal importance is the inclusion in a license agreement of the Gilpin Mills of the only known transcript of the patent of Cyrus Austin on the use of chlorine for bleaching rags and paper granted by the United States in 1798.*

Joshua and Thomas Gilpin founded the first paper mill in the state of Delaware in 1787—the year of the American Constitution. The Gilpin brothers were the sons of a famous father, Thomas G. Gilpin, a friend of Franklin and an ardent Quaker. Thomas Gilpin, Sr. was not only successful in business but also inherited extensive properties in Maryland and Delaware. At the time of Joshua, Sr.'s death in 1778, the two sons were children. Joshua was 12 years old, and Thomas less than 2.

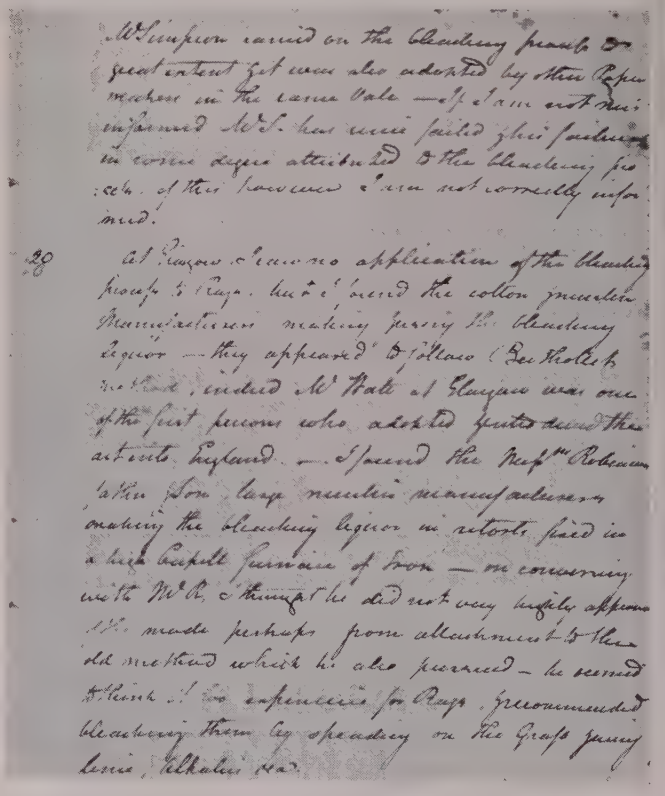
The boys were given the best education that Philadelphia could afford. Joshua studied law but never actually entered the profession Thomas, in particular, showed a remarkable interest and ability for mathematics and science. The exact story, however, as to how and why the two brothers, one aged 22 and the other aged 11 started a paper mill may never be known. We do know that they were assisted by their maternal uncle, Miers Fisher, in the early days of the venture. Perhaps the uncle actually ran the plant during the initial stages while the elder Joshua supervised the many family properties and the very young Thomas devoted himself to studying the technical problems of a paper mill (*2, 3*).

According to Dard Hunter, the earliest printed description of the Gilpin Paper Mills appeared in the account of Jacques Pierre Brissot de Warville's travels in the United States during the year, 1788. The statesman wrote of his trip to Wilmington and his visit to the Gilpin Mill in 1788 in the following words.

". . . I set out from Philadelphia for Wilmington, distance twenty-eight miles, and road tolerably good. The town of Chester, fifteen miles from Philadelphia, is a place where strangers like to rest. It stands on a creek, which falls into the Delaware. It enjoys some commerce, and the taverns here are good. Wilmington is much more considerable; it stands likewise on a creek near the Delaware; the basis of its commerce is the exportation of flour. One mile above Wilmington, you pass the town of Brandywine; the name of which will call to your mind a famous battle gained by the English over the Americans, eight miles from this town, on a river of the same name. This town is famous for its fine mills; the most considerable of which is a paper-mill belonging to Mr. Gilpin and Myers (Miers) Fisher, that worthy orator and man of science . . . Their process in making paper, especially in grinding the rags, is much more simple than ours. I have seen specimens of their paper, both for writing and printing, equal to the finest made in France" (*4*).

By the year 1795, Joshua, the elder brother, was 30 years old. The family business was successful and with his Mother in excellent health and with his brother actively operating the paper mill on the Brandywine, he decided to visit Europe to satisfy a desire that he had had for many years.

Joshua sailed for England in 1795, and did not return to America until 1801. In England he visited all the great manufacturers and studied mining operations and metallurgical enterprises. He visited the great works of Watt and Bolton at Soho (*5*). Of particular interest to us however is the fact that he visited most of the paper mills of England and Ireland and most of the bleaching establishments where the new chemical methods of bleaching with chlorine had only shortly been introduced from France. Not only did Joshua make notes of his visits to these paper mills in his journal, but he also wrote detailed letters and technical surveys about chlorine bleaching to his brother, Thomas. These letters and surveys are a part of our manuscript records and give a first-hand account of the very earliest operations.†



Leaf from Joshua's report on chlorine bleaching

* Joshua's writings are on 48 leaves and on one side of each leaf only. The first 36 leaves show no chain lines and bear watermark: "I. Taylor 1794." The following 16 leaves show chain lines and bear watermark: "I. I. Arking, 1796." The plans of the bleaching room and the patent agreement are on paper made at the Gilpin Mills bearing watermarks: "T. Gilpin Co." and "Brandywine."

† In the Division of Public Records, Commonwealth of Pennsylvania, Harrisburg, Pa., are deposited the journals kept by Joshua Gilpin during his visit to Europe. The records are dated from 1795 to 1801. These journals record the visits to various paper mills in England and Scotland which are discussed in detail in our manuscript records.

New Nalco Coagulant makes Larger, Heavier Floc . . . Faster

Radically different Nalcolyte 110 used with Conventional Chemicals to Cut Costs, Speed Action in Water Clarification

Photo taken in Nalco Laboratories 7 seconds after agitation stopped: *Left*, Control sample of untreated turbid water; *center*, same water, treated with 50 ppm alum; *right*, same water, treated with 20 ppm alum, 1 ppm Nalcolyte 110. Note that large, dense floc is settling out much more rapidly than center alum-treated sample.

Nalcolyte 110 is a new, non-ionic high polymer flocculant of very high molecular weight—over 1,000,000. It is used in extremely small dosages with conventional coagulants (such as sodium aluminate, alum, ferric sulfate) to increase size, density and uniformity of floc.

Less Chemical; Greater Capacity

Action of Nalcolyte 110 in creating heavier, larger, faster-settling floc not only permits greater throughput rates without floc carryover to processing equipment, but also cuts the total chemical requirements at a resultant cost saving.

In the example illustrated above, only 40% as much alum is required when Nalcolyte 110 is used.

May be Used in Potable Waters

Approved by the U. S. Public Health Service Technical Advisory Committee for use in treatment of public water supplies, Nalcolyte 110 gives water works the opportunity to get appreciably greater capacity from existing clarification equipment—at lower treating cost.

High Suspended Solids No Problem

Waters containing high suspended solids respond quickly to Nalcolyte 110 coagulating action . . . frequently without other coagulant chemicals.

Typical high suspended solids waters which can be treated with speed and economy with Nalcolyte 110 are paper mill white water systems, industrial waste waters, mineral slurries and blast furnace gas wash water slurries.

Nalcolyte 110 Easy to Handle

Nalcolyte 110 is a coarse, white, free-flowing powder of non-toxic character. It is fed in dilute water solutions with standard liquid proportioning pumps or feeders. Stock solutions are prepared at concentrations up to 20%. Packaging is in convenient 25-lb. bags.

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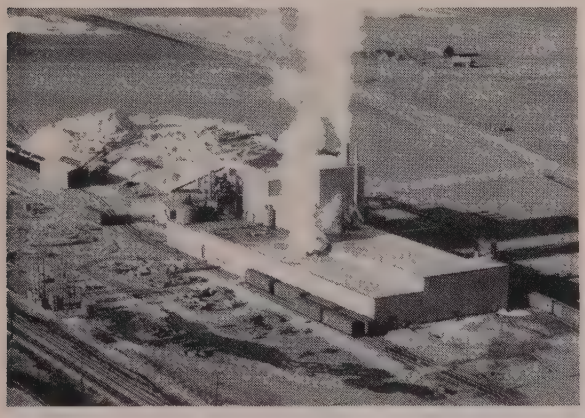
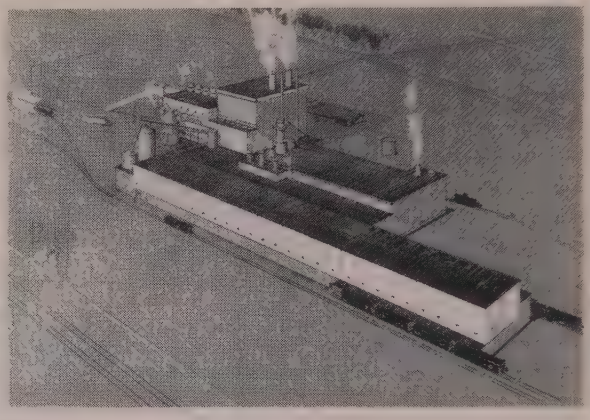
Nalco CHEMICALS

Waldorf-Hoerner unfolds spectacular expansion

FIRST STEP in the creation of Montana's first completely integrated pulp and board facility is shown in this photo of Waldorf-Hoerner's chemical pulp plant, completed in 1958.



ADDITION OF PAPER MILL, as it will appear when finished, is shown in drawing above. Building is 700 feet long and 70 feet wide.



...with advanced production techniques featuring

DORR-OLIVER EQUIPMENT

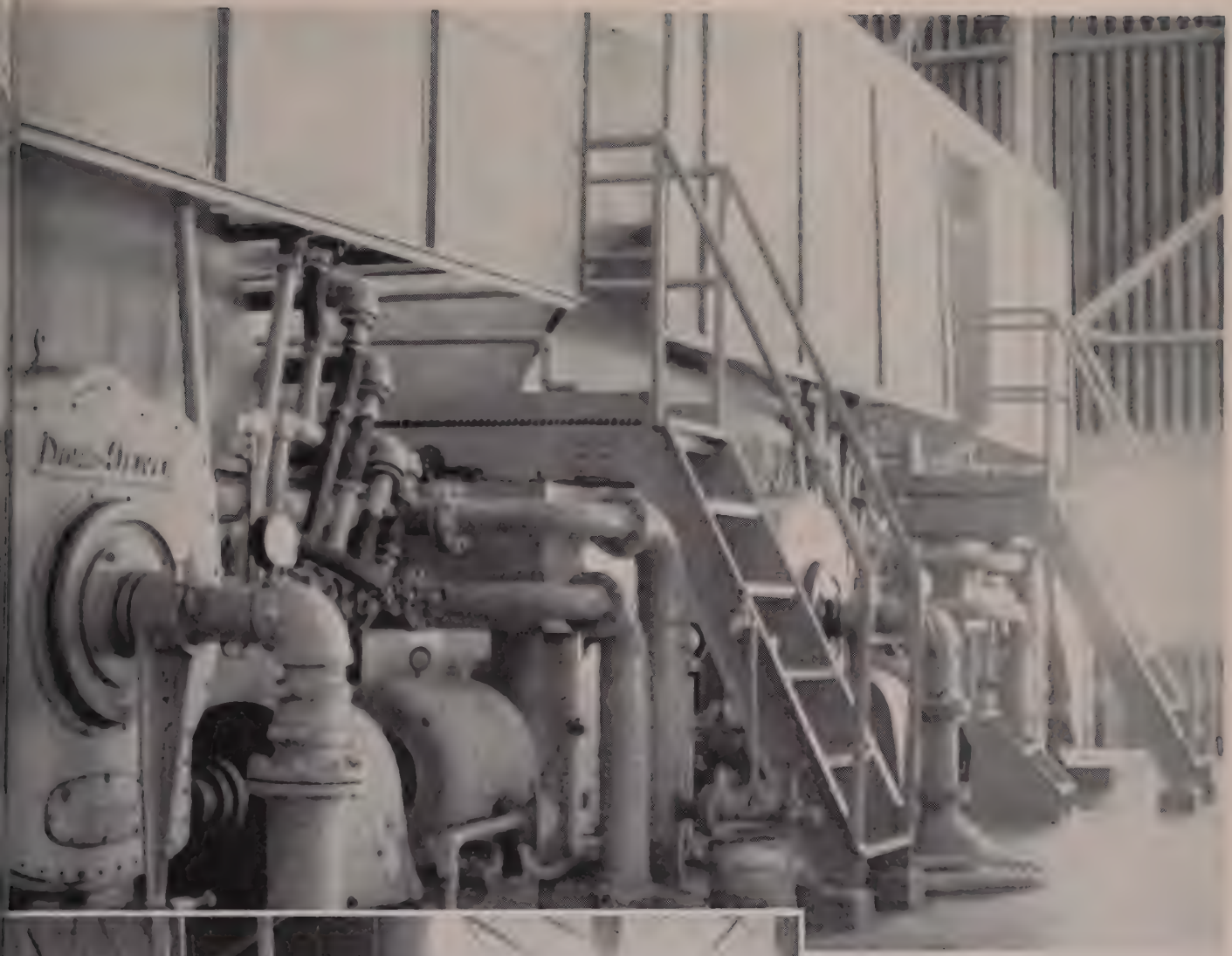
Rapid expansion, development of many innovations in production and the use of proven Dorr-Oliver systems and equipment are features of the spectacular operation of the Waldorf-Hoerner Paper Products Co., at Missoula, Montana.

The chemical pulp mill, producing unbleached kraft pulp, now includes an Oliver Brownstock Washing System with three 11½ ft. dia. x 20 ft. face single drum washers.

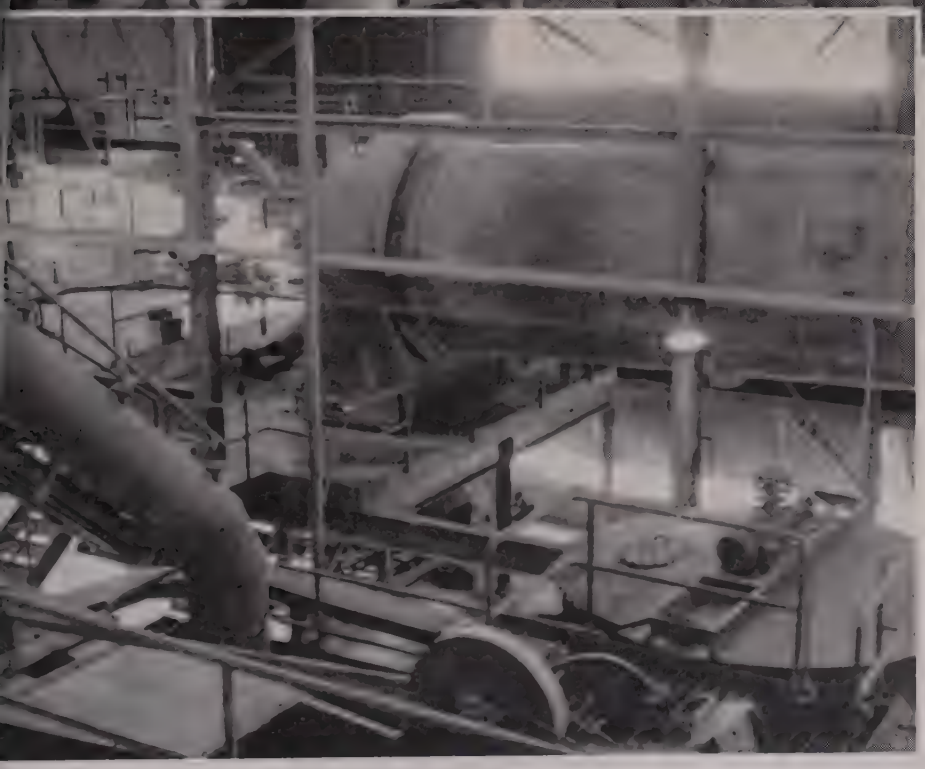
The Dorr Recausticizing System, of unconventional and simplified design, has both primary and secondary slaking, a single compartment Green Liquor Clarifier, unit-type White Liquor Clarifier, two-stage Lime Mud Washer and Dorr-Oliver Hot Lime Crusher. A new Lime Mud Washer is being added which, with minor rearrangement of existing equipment, will provide up to 700 TPD of liquor making capacity.

The Waldorf-Hoerner expansion program will utilize a complete Dorr-Oliver bleach plant and water treatment facilities to provide an integrated pulp and board operation.

For more information on the full range of Dorr-Oliver equipment and services for the pulp and paper industry, write to Dorr-Oliver Incorporated, Stamford, Connecticut.



OLIVER BROWNSTOCK WASHING SYSTEM comprises three 11½ ft. dia. x 20 ft. face drum washers, each operating single stage but capable of two-stage operation.



PART OF THE DORR RECAUSTICIZING SYSTEM is seen in this photo, looking across the slaker to the lime kiln. System is highly instrumented and incorporates advances in design which simplify operation and improve recovery.

DORR-OLIVER

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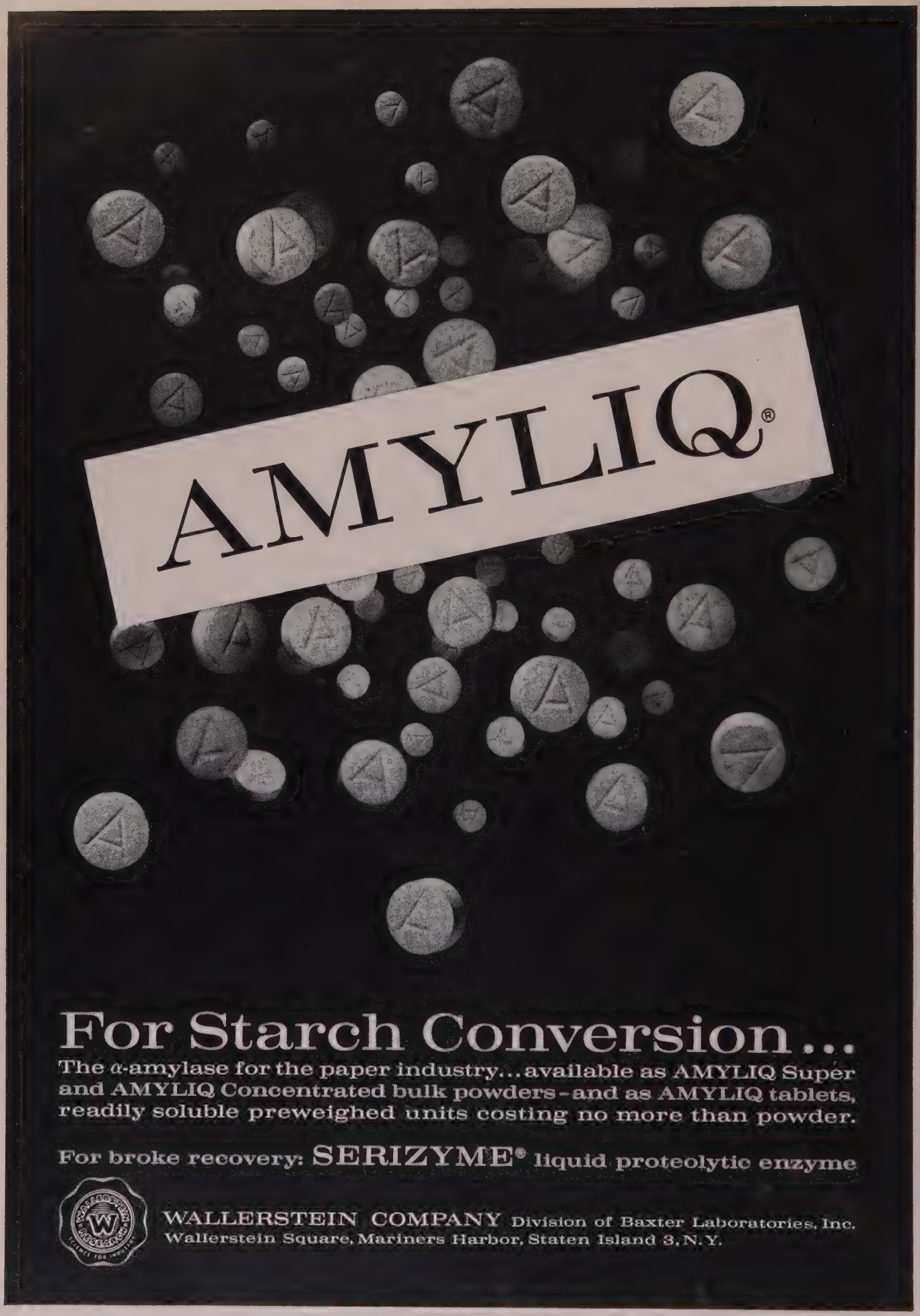

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the question is time

During the past few years, the cancer cure rate has increased from one in four saved to one in three saved: 40,000 more lives saved each year. During the next few years, there will no doubt be new methods of diagnosis, and even cures for some cancers that are considered incurable today. In time, the ultimate goal, cancer prevention, will be achieved. But time alone will not do the job. ● Time plus research will. Research costs money. In the past 14 years, the American Cancer Society has spent about $76,500,000 on cancer research. Much more is needed to accomplish the final conquest of this dread disease. Give generously. Send your contribution to "Cancer," in care of your local post office.

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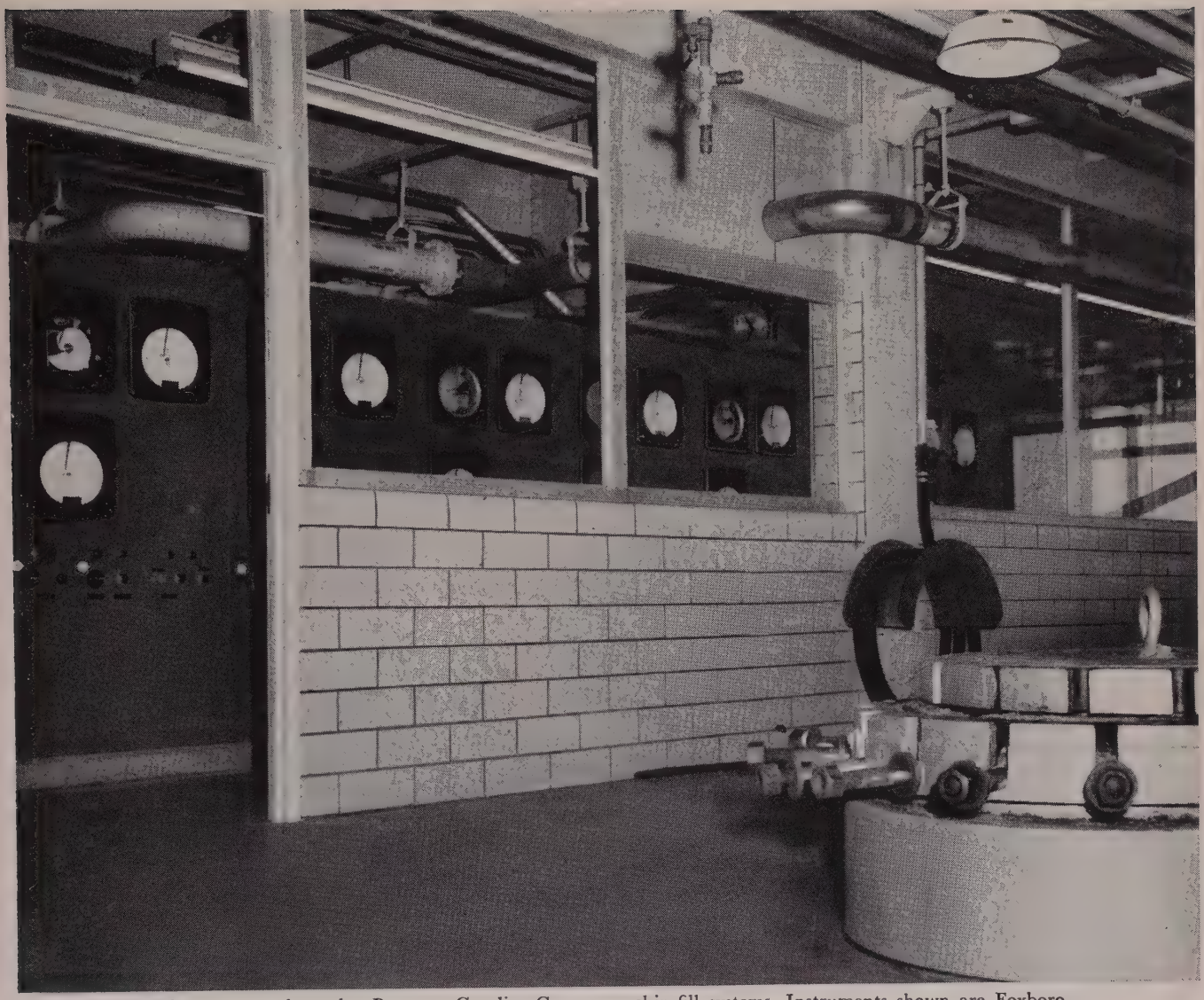
the answer is money

guard your family...fight cancer with a checkup and a check



Digester control panel at Bowaters Carolina Corp., Catawba, S. C., containing 5 Foxboro Digester Control Systems, together with liquor-fill and chip-fill systems. Instruments shown are Foxboro cam pressure controllers, digester top-and-bottom temperature recorders, and relief flow controllers.

BOWATERS CAROLINA CORP. REPORTS:

"Uniform pulp – cook after cook with Foxboro Automatic Digester Control"

Completely automatic from fill to blow — that's the operation of the five, 4,300 cubic-foot kraft digesters at Bowaters Carolina's new mill at Catawba, S. C.

Each of Bowaters Carolina's five digesters has its own Foxboro packaged control system. To start a cooking cycle, the operator simply turns a single knob — then Foxboro takes over. Results: perfectly controlled digester circulation with virtually no liquor pull-over; uniform permanganate; practically no rejects — all resulting in high yield and excellent uniformity.

Your digester control story can be the same, too. Get full details on this revolutionary kraft digester control system from your nearby Foxboro Field Engineer. Or write direct for engineering data sheet 260-50 which has full information. The Foxboro Company, 784 Neponset Avenue, Foxboro, Massachusetts.

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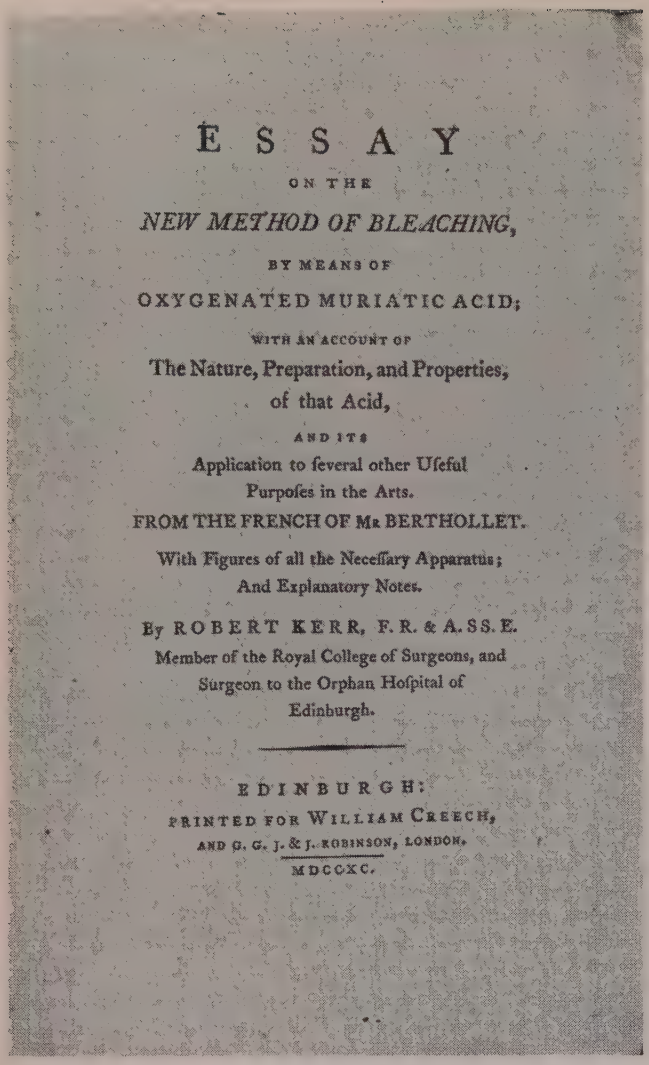
AUTOMATIC DIGESTER CONTROL



ESSAY

ON THE

NEW METHOD OF BLEACHING,

BY MEANS OF

OXYGENATED MURIATIC ACID;

WITH AN ACCOUNT OF

The Nature, Preparation, and Properties,

of that Acid,

AND ITS

Application to several other Useful

Purposes in the Arts.

FROM THE FRENCH OF Mr BERTHOLLET.

With Figures of all the Necessary Apparatus;

And Explanatory Notes.

By ROBERT KERR, F.R.& A.SS.E.

Member of the Royal College of Surgeons, and

Surgeon to the Orphan Hospital of

Edinburgh.

EDINBURGH:

PRINTED FOR WILLIAM CREECH,

AND G. G. J. & J. ROBINSON, LONDON.

MDCCXC.

Title page of Kerr's translation of Berthollet's work on chlorine bleaching, Edinburgh, 1790

Until the discovery of the bleaching action of chlorine, rags were bleached or decolorized by boiling in alkali and exposing them to the sun over a long period of time. Many colors in the rags could not even be removed by this method. The advent of chlorine bleaching not only furnished a method for speeding up the process of obtaining satisfactory material for use in making paper, but many types of rags could now be decolorized which heretofore had been useless in the manufacture of paper. Joshua's visit to England took place at just about the time when the process was widely being put into practical use.‡ His own words written between 1795 and 1801 give us the thrilling story of this beginning. Joshua wrote to his brother:

"The new mode of bleaching consists in adopting in lieu of the former processes the application of the oxygenated muriatic acid§ either in the acid or simply in the state of gas or vapeur.

"We are indebted to Scheele the Swedish chymist for the discovery both of the oxygenated muriatic acid itself and of its properties in changing all substances into a perfectly white color. Scheele however went little further than establishing the fact and shewing its application to the bleaching manufacture . . . his improvements were confined I believe wholly to the operation of the gas itself.

"Berthollet, The French Chymist entered most actively into experiments on the subject and we are indebted to him principally for the introduction of the art into its present extensive operation . . . his experiments were first published in papers addressed to the Academy at Paris in the Annalls de Chimie . . . they were afterwards comprised in a small volume which has been translated by Mr. Kerr . . . Berthollet finding the inconveniences of applying the acid in the state of gas or vapeur, substituted the condensing and mixing it with water as to form a highly acidulated liquor.

"Since the process has been known in England it has been adopted in various ways and received numerous improvements both here and in France. Several patents have been taken out most of which I shall explain; in general however it may be remarked that all are but variations or different applications of the same principle. And that as yet it appears far from having arrived at the perfection which there is every reason to believe it will attain.

"One of the latest short works on the subject is that entitled, "The Art of Bleaching by Pajot des Charmes" translated by W. Nicholson . . . this is an elementary work taking up the processes of M. Berthollet and explaining the best methods of surmounting the difficulties he had experienced and of carrying this principle into compleat effect. It seems in fact to be a summary of what has been done in France on the subject; it is to be regretted one has not some work comprising the processes of the English Manufactories especially those of Manchester Glasgow and where as well as in Ireland the new bleaching process has been adopted to considerable extent. In effect: the English artists however in general content themselves with establishing processes suited to their own operations and tho the principles and practice of this art are now neither secret nor new tis alone by actual inspection, that we are left to collect everything beyond merely the publication of the patents or some works more of scientific than of practical men . . . this is the more to be regretted as in the infancy of a process which promises to be of such general use, the communication of facts attending its improvements would tend to perfect it more speedily than any other method.

"The leading application of the bleaching process was ob-

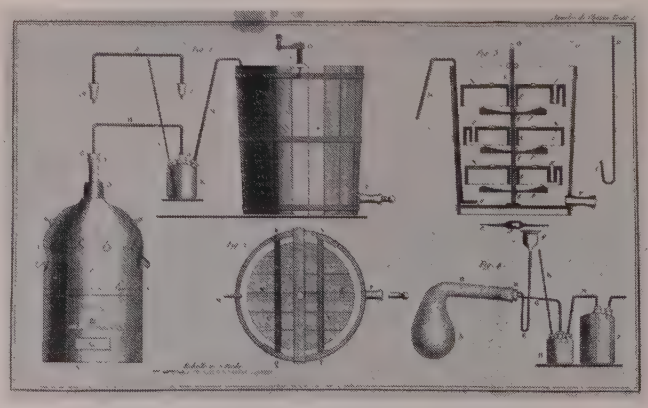


Plate from Berthollet's French work on chlorine bleaching. Shows apparatus for making chlorine solutions and bleaching apparatus. Paris, 1786

‡ Scheele first prepared chlorine in 1774 by the action of manganese dioxide on hydrochloric acid. Scheele thought that the gas was the acid deprived of "phlogiston," and called it "dephlogisticated muriatic acid." It was believed to be a compound until 1810 when Davy proved its elementary nature. Scheele early noted chlorine's decolorizing action, but Berthollet first proposed its use as a commercial bleaching agent in 1785. According to Clows, the process was introduced into Scotland by two routes. The first was through James Watt who learned the process directly from Berthollet in 1786 or 1787 and put it to work at his father-in-law's (MacGregor) bleachery by 1788. The second route was through Patrick Copland of Aberdeen, who learned the process from Professor DeSaussure of Geneva in 1787. Copland communicated the process to Messrs. Gordon Barron and Co. of Aberdeen who had the process in operation commercially by July, 1787.

§ By 1795 the "phlogiston" theory had been discarded by most chemists. Instead of things giving up "phlogiston," in combustion reactions, it was now felt that oxygen was taken up instead. The dephlogisticated muriatic acid had now become oxygenated muriatic acid. It was not to become chlorine until 1810.

"Reliance V★S Drive provides 60-second acceleration and precise tension control of Cameron winder

H. E. Stebner, Paper Application Engineer, Reliance Electric & Engineering Co.

"At speeds of 6,000 FPM, one of the keys to precise tension control of newsprint is electrical regenerative braking on the unwind stand. A Reliance D-c. motor powering the unwind roll acts as a drag generator, maintaining critical tension.

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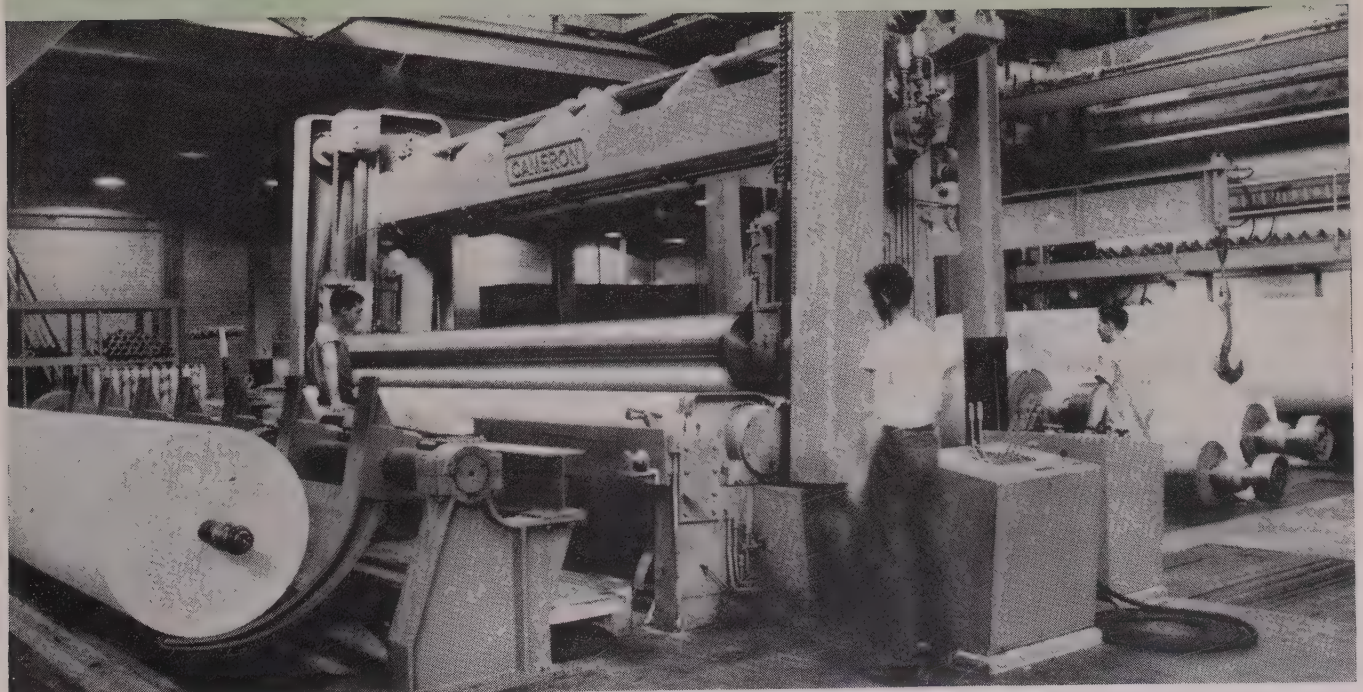
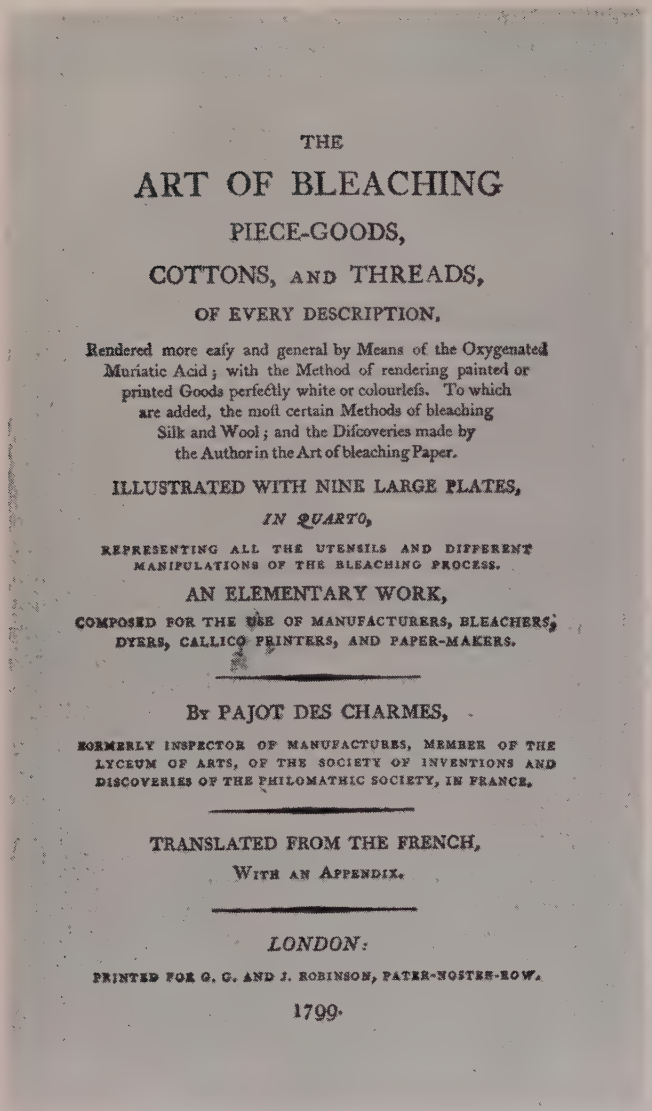




THE

ART OF BLEACHING

PIECE-GOODS,

COTTONS, AND THREADS,

OF EVERY DESCRIPTION,

Rendered more eafy and general by Means of the Oxygenated Muriatic Acid; with the Method of rendering painted or printed Goods perfectly white or colourlefs. To which are added, the moft certain Methods of bleaching Silk and Wool; and the Difcoveries made by the Author in the Art of bleaching Paper.

ILLUSTRATED WITH NINE LARGE PLATES,

IN QUARTO,

REPRESENTING ALL THE UTENSILS AND DIFFERENT MANIPULATIONS OF THE BLEACHING PROCESS.

AN ELEMENTARY WORK,

COMPOSED FOR THE USE OF MANUFACTURERS, BLEACHERS, DYERS, CALLICO PRINTERS, AND PAPER-MAKERS.

By PAJOT DES CHARMES,

FORMERLY INSPECTOR OF MANUFACTURES, MEMBER OF THE LYCEUM OF ARTS, OF THE SOCIETY OF INVENTIONS AND DISCOVERIES OF THE PHILOMATHIC SOCIETY, IN FRANCE.

TRANSLATED FROM THE FRENCH,

With an Appendix.

LONDON:

PRINTED FOR G. G. AND J. ROBINSON, PATER-NOSTER-ROW.

1799.

Title page of English edition of Pajot des Charmes' work on bleaching. London, 1799

viously first to whitening cotton, linen and other cloths . . . that of rags however for paper struck almost the first discoverers: the only difference between the sepertive articles is that cloths of every kind will bear the expence of a far superior process; while the application to rags must be very cheap in order to be useful . . . in what I now mention I shall very much confine myself to the process particularly applicable to the paper manufacture.

"All the processes mentioned by the French chemists and indeed most of those known in England have combined the application of the muriatic acid‖ . . . with the use of lees or alkalies generally resembling (?) in many respects from the processes formerly in use . . . Berthollet's method in general consisted in many alternate immersions in lees and in the bleaching liquor; it must be obvious however that the labor which these repeated operations demand cannot be introduced into the paper manufacture at least in the bleaching of the rags, as no saving will bear it: it can alone be useful by a cheap application of the principle with little labor and cost of the materials used.

"The general principle on which the whole process rests seems to be no more than giving a quick and superior affect to the action of that part of the common air of the atmosphere which is called oxygen . . . neither of the two acids or salts employed with the sulfuric, or the muriatic possess this quality either singly or combined together, or with any substances which do not afford a large portion of oxygen or vital air nor has the manganese any other effect than being a cheap substance which yields a very large quantity of such air.

"The process indeed may be termed little more than quickening that operation which nature is constantly carrying on in the open air where goods of every kind, in particular such substances as are now described are deprived of their color by simple exposure and more or less time in India, many parts of France and other countries. No method is used but simple exposure to the sun, dews, grasses: we know the affect of long time on almost every substance particularly how the best ink becomes discharge from paper, especially if not carefully kept from exposure to the atmosphere.

"There seems to be a strong disposition in Sulphur to combine with and quicken the operation of the atmosphere. Most substances particularly woolen goods are made white by being exposed to its fumes in a close room—an acidulated liquor formed of it is used to bleach linen. If paper which has been written on for almost any length of time be immersed in a solution of oil of vitriol in water, the ink will become nearly discharged.

"The oxygenated muriatic acid is produced by simply mixing common salt, called chemically muriate of soda. Oil of vitriol called sulphuric acid and manganese . . . (an earth consisting chiefly of a decomposed iron ore,¶ and found often and in large quantities) together in proper proportions in vessels calculated simply to distill them . . . the union of these several substances especially if assisted by a moderate heat, begins immediately to produce a strong vapeur or gas called the oxygenated muriatic acid gas, and if this be conducted into vessels filled with water, it combines with the water to produce the oxygenated muriatic acid.

"There are several objects necessary to be known and attended to in the outset of these processes. First, that it is exceedingly prejudicial to the health of those who use it without proper precautions which however are affectual. Secondly, that in carrying it on both the utensils and place in which it is done must be formed without metals particularly iron to which the gas and liquor have a strong attraction and will soon destroy . . . lead however resists its action and may be usefully employed in all its processes . . . the precautions with respect to health will be mentioned in their proper place . . . and with respect to the action of the acid on metals it is only to shew the propriety of fixing on a place such as an outhouse or building in some degree detached from another in order to carry on the process, it need however not be at any material distance. (At Brandywine I should think at the end of the screening house or at the end of the waterwheel . . .)

"I have not by me Scheele's experiments. They may however be attended to advantage as his experiments allude to the simple application of the gas itself which as it is infinitely less laborious than forming it into a liquor and appears far more proper for the paper business than the more tedious and expensive one of the liquor.

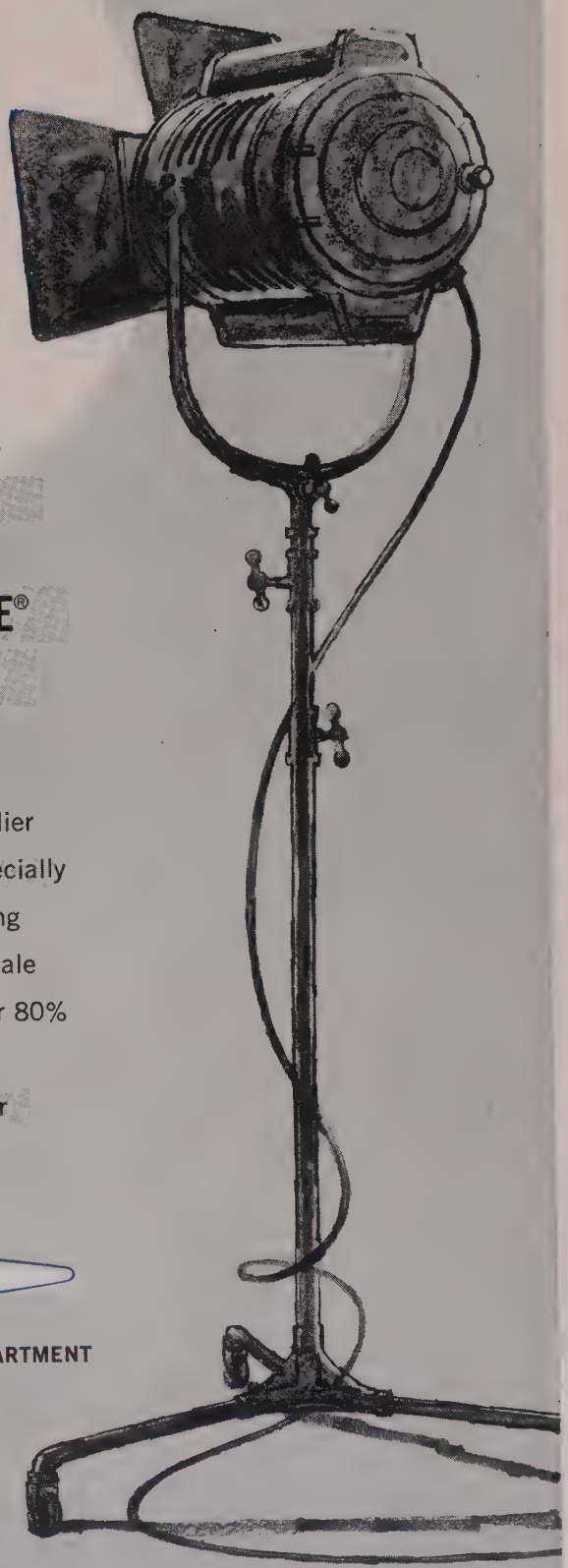
"Scheele met with many difficulties, the chief of which were to submit the cloths and substances to an uniform action of the gas which being necessarily confined in close vessels, the cloths were but partially acted upon; this difficulty may be not only removed with respect to rags but is not at least of the same moment as in piece goods whose preservation and being perfectly whitened throughout were objects of the first consideration.

"From the difficulties occurring to Scheele, Berthollet's attention was principally devoted to conducting the process by the liquor . . . he distilled the above articles in a glass re-

‖ Gilpin must have meant oxygenated muriatic acid.

¶ By manganese, Gilpin meant pyrolusite or manganese dioxide. Gilpin should have known that this mineral was not "decomposed iron ore," for by 1774 Gahn had isolated the metal, manganese, and shown that pyrolusite was a "calx" (oxide) of this different metal.

ACCOBRITE



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tort laid in a proper furnace and conducting the gas into a tub filled with water, impregnated the water and thus formed a liquor in which he afterwards immersed the substance to be bleached . . . these immersions were often repeated and made also alternately in Lees, or solutions of alkalies . . . they were altogether tedious and expensive and not successful to a degree proper to be adopted in bleaching of rags . . . His work however is to be read as offering at once all the principles giving compleat personal knowledge of the whole process.

"M. Des Charmes, taking up the difficulties which Berthollet met with first enumerates the various methods he has taken to obviate them, and then proceeds to an ample description of the whole improved process such as it has been carried into affect in France . . . His process is extended not only to bleaching rags and paper itself, but to a variety of other substances and also to an application of the oxygenated muriatic acid to dyeing and to a variety of other useful objects . . . His book in fact forms a compendium of what has been done on the subject in France . . . Not only from his immediate process a good mode of bleaching paper may be formed, but through a variety of hints scattered thru his work which may form the basis of carrying the art far beyond its present perfection.

"The only publication which I have yet met with in England on the subject are translations from the French, and the specification of patents mentioned in the Repository . . . there may however exist elementary works with which I am not acquainted but I suspect as yet nothing has been published which is not comprised in the works I have mentioned, and that I apprehend the bleaching of rags in a cheap simple manner yet remains an important object for future experiment.

"The several improvements or methods for which patents have been obtained, all of them which have come to my knowledge are no more than variations of the methods laid down by the French chemists and most of them so little vary from them as scarcely to possess any originality . . . I shall however describe them.

"After thus describing what has been published on the subject I shall mention what I have seen carried into effect in Europe.

"The first opportunity I had of observing the bleaching process was at the mills of W. Simpson near Polton Bank in the Vale of Poplin near Edenburg.** This gentleman in a handsome manner communicated to me all his process. I found him applying the gas immediately to the rags. His furnace was of simple brick in one of the outer rooms of his mill; I believe he ran the rags thro the washing engine before he submitted them to the gas. He also boiled them in lees and this he proposed as highly useful not only in the bleaching but to destroy the hard remains of flax in the coarse linens which were the chief objects of his attempts . . . I think his retorts were of lead, and the gas condensed into troughs of deal (pine) of about 11 feet long 4 wide and 3 deep in which the rags were inclosed . . . I do not think he had adopted any mode for preventing the effects of the gas on the workmen, but opening the doors and letting the gas go off when the boxes were opened before the rags were taken out. I may not however be correct in remembering this circumstance. W. Simpson carried on the bleaching process to a great extent and it was also adopted by other papermakers in the same vale . . . If I am not misinformed W. S. has since failed and his failure in some degree attributed to the bleaching process, of this however I am not so surely informed.

"At Glasgow I saw no application of the bleaching process to rags, but I found the cotton and muslin manufacturers making and using the bleaching liquor . . . they appeared to follow Berthollet's method, indeed Mr. Wate (Watt?) at Glasgow was one of the first persons who adopted and introduced the art into England. I found the Messrs. Robinson, Father and son, large muslin manufacturers making the bleaching liquor in retorts laid in a high cupell furnace of iron . . . On conversing with Mr. R. I thought he did not very highly approve of the mode perhaps from attachment to the old method which he also pursued . . . he seemed to think it too expensive for rags, and recommended bleaching them by spreading on the grass and using lime, alkalies, leas.

"At S —— in Yorkshire, I saw a mill of (Simpson?) Brothers, the younger of whom had been brought up in Kent and had founded the mill here upon the newest and best construction, it had been built but a year or two when I saw it in Nov. 1795 and the bleaching process had not then been introduced into it. I saw it again in Novem. 1799, when they had introduced it in the best and simpliest manner I have seen in England but as I mean to describe this method fully I shall not enlarge upon it here.

"In the spring of 1796 I visited the Kent mills and found the bleaching process had been taken up on a very extensive scale by many of them especially the Taylors†† . . . I particularly visited Mr. Smith's mill which had been built especially to carry on this process: I found him using the liquor which he made in a room adjoining the Engine . . . His furnace was a simple square brick one about 6 feet long 4 high and 2 wide. On the top a rim of iron enclosed the sand in which the retorts stood . . . The retorts were of stoneware made at Lambeth of the size of about 1 gallon . . . The tubes were of cane or reed and luted I think with clay: there were I think 8 of these fixed in the sand and all conducted into a (lead?) receiver. The liquor was run into a cistern below the engine house and pumped up into the troughs in which it was applied to the rags . . . The rags are first washed in the engine and then let into the troughs and the liquor put upon them.

"I did not see the process at Mr. Taylors so well as to describe it. In his mill however and indeed in all the other Kent mills which I saw, the liquor was acid and I derived much information which will appear in the course of my observations.

"After thus mentioning the history of this process and the observations I have made, I shall now proceed to a description of it in all its parts.

"First as to the materials . . . The article of salt is too common and too well known to need much being said about it . . . The strong dark salt is most recommended, it must be prepared by drying it very well pounding and sifting it fine as an intimate mixture of it with the manganese is of much consequence.

"Secondly. The manganese is a black metallic earth composed chiefly of iron and oxygen when broken if of the best sort it sparkles in fine brilliant needles. ‡‡ Its general resemblance is very similar to lumps of fine pure smiths cinder or a black calx of iron . . . It may not be difficult to find it in America, until it is however it may be imported from London, Dublin, Bristol; indeed it is now a considerable article of commerce though not long since a neglected earth. The coast of Ireland abounds with it. The London price is (?) if not pure it will only require a greater quantity . . . It is acid in its original state as I know of no change it undergoes other than beating and sifting it very fine . . . that sort however should be chosen which is clean of all other stones as far as possible.

"It is to be observed that as the manganese is used solely to supply the oxygen any substance containing oxygen uncombined with other injurious to the process may be used. Nitre itself can yield an immense quantity of the oxygen, but where manganese is to be had nothing is more cheap.

"It would be worthwhile in carrying on the (?) process

** Joshua's journals in the Division of Public Records at Harrisburg contain details of visit to Simpson's mill with date, Oct. 14, 1795.

†† Joshua's journals record visit to Taylors, March 8–12, 1796; also visit to other mills in Kent during this period.

‡‡ See note ¶ on page 52 A.

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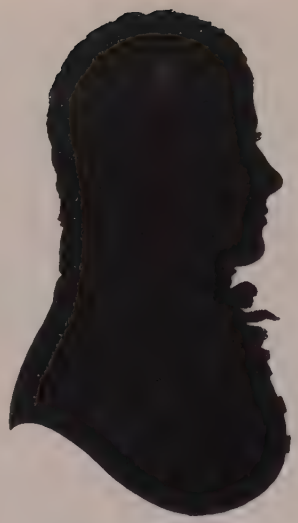
Joshua Gilpin (courtesy Hagley Museum)



Thomas Gilpin (courtesy Hagley Museum)

to have a small water works connected with the mill to grind the salt and manganese and to mix them.

"Thirdly, the sulphuric acid or oil of vitriol as the carrage of this article is not only expensive but subject to continual hazard, it would be a highly beneficial manufacture of itself in America§§. . .Until it is made there however it must be imported and may be ordered from London, Liverpool, Bristol or Dublin. It costs about 6½ sh. per lb. It would be an object to make it and I think might well be combined with the bleaching process as it requires a room of lead, the floor of which is covered about 1 or 1½ inch with water and sulphur mixed with saltpeter is placed in the room in a leaden pan and set on fire then it is left to burn and the vapeurs of the sulphur are attracted by and impregnates the water. . .

"The reasons for thus making the sulphuric acid are that I think the same room might advantageously be used for exposing the rags to the gas . . . It strikes me also that perhaps the very process itself of making oil vitriol might be used to bleach. This however is an object of future research.

"Oil of vitriol of the proper degree of strength will bear double its quantity of water i.e. 6 of oil vitriol and 12 of water . . . The strength of the oil of vitriol may be known first by weighing it as one gallon will weigh (?) lbs. . . . 2dly by the areometer . . . this however is not always to be had . . . the common oil of vitriol may be depended on until our own experience teaches how to ascertain its qualities better . . .

"It is almost needless to say that the common muriatic acid and manganese will answer every purpose of oil and vitriol and salt . . . because first it is still more difficult to procure them than oil vitriol and secondly, it is very offensive to the health.

"The manganese and salt being separately pounded and sifted are to be mixed very intimately together so that they appear entirely as one substance . . . The sulphuric acid is not to be applied till the materials are in the retort and the whole ready as the process commences instantly on its application.

"The best proportions which have been adopted on experience are 6 parts sulphuric acid . . . 12 parts water 8 parts salt and of good manganese 3 parts . . . If of inferior quality more is necessary . . .

OF THE UTENSILS

"As it is of the utmost consequence to make the establishment useful by being cheap I should try it in the simpliest manner . . . both Berthollet and M. Des Charmes shew the furnaces that may be used . . . a common iron or even earthern pot (even if broken of little consequence for a sand bath) may be placed in a few bricks so as to have fire under it, in fact any place in which a retort or vessel can stand in sand or water which can be heated will do in a small work . . . In a large one a furnace should be built in the middle of a room just so as to contain a hollow on its top for the insertion of the retort or retorts.

"In the large manufacturers at Manchester they use cast iron retorts lined with lead the retorts being fixed in brick work, . . . These retorts are very similar to the iron pots used in the vats for making paper, such pots standing on their bottoms . . . on the top of these retorts are fixed leaden heads formed in one piece with leaden pipes or conductors as it is of consequence to prevent having any joints if possible."

In the autumn of 1801 Joshua returned to the United States. On his return he found that his brother, Thomas, had grown to manhood and their business interests were flourishing. Particularly, the paper mill on the Brandywine had been enlarged and business was good (*2*).

Obviously, the brother's early interest in adapting chlorine to the bleaching of rags must have been one of the principal objects of their collaboration for the next several years. Also during this period an English papermaking expert, Lawrence Greatrake, had been engaged and was probably given an interest in the mill.‖ The manuscript records indicate that Greatrake took an important part in the "Bleaching Experiments."

By April 19, 1804, Greatrake and the Gilpins had decided to use the chlorine bleaching process of an American, Cyrus Austin, for in our records from the Gilpin Mills there is this agreement for a license to use this process:

"Agreement William Stidolph with
Laurence Greatrake for Right to bleach Rags, Pulp etc.
at the Brandywine Paper mill under his patent . . .

"Whereas by virtue of a certain agreement made and signed the 19th day of April 1804—between Laurence Greatrake of Christianna hundred county of New Castle and William Stidolph of the said County the said William Stidolph did agree in consequence of certain conditions to be performed on the part of the said Laurence Greatrake and also for the sum of five hundred dollars to be paid to him in hand as a

§§ Actually, American sulfuric acid was first manufactured commercially in 1793 in Philadelphia by John Harrison (*7*).

‖ Joshua's journals at Harrisburg say that on March 22, 1796, he went on to Two Waters and sent for Lawrence Greatrake who lives at Apsley Mills and that on March 25 he visited Greatrake's mill which was old and patched.

GILPIN'S PAPER MILLS. BRANDYWINE

Gilpin Paper Mills. Early 19th century (courtesy Hagley Museum)

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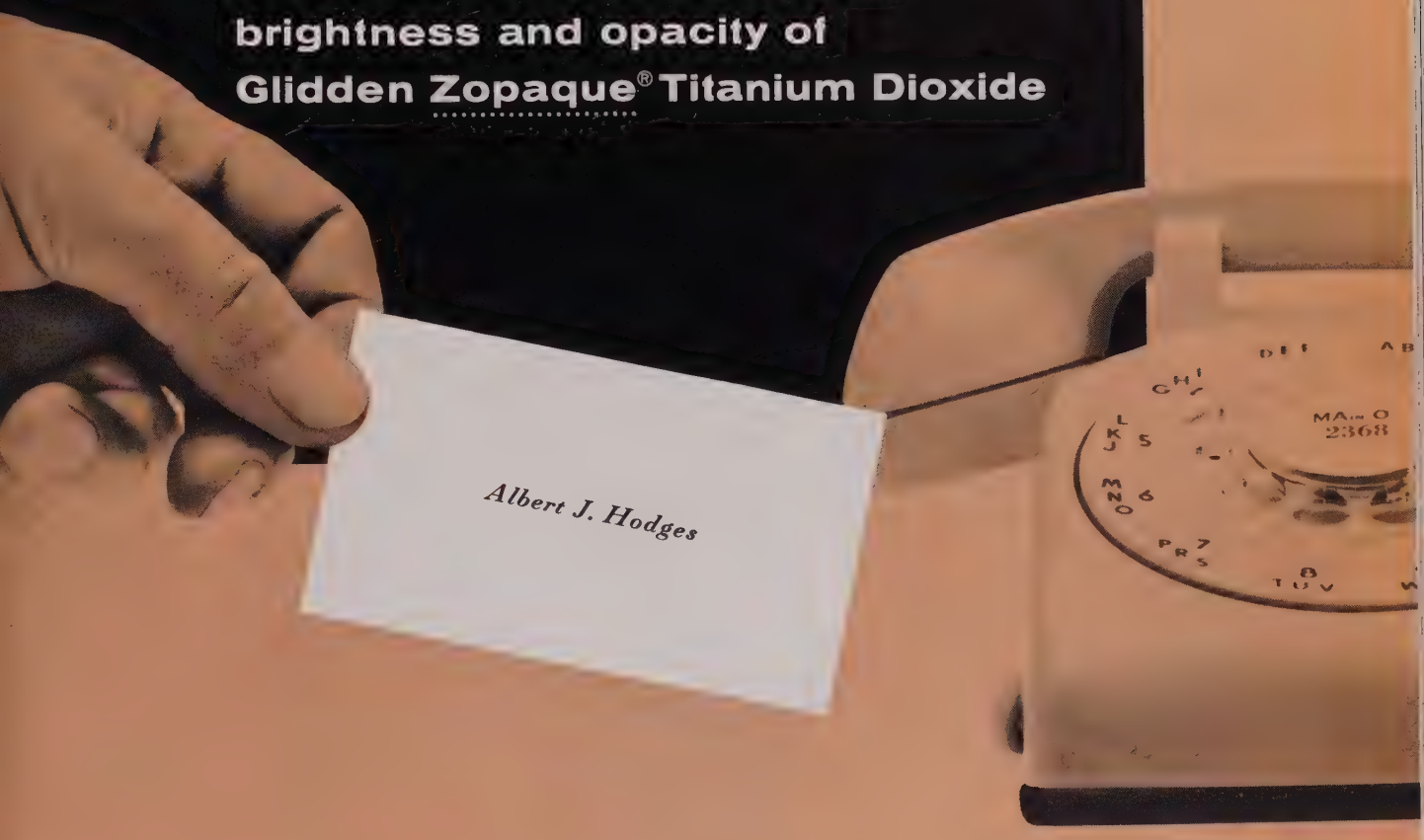

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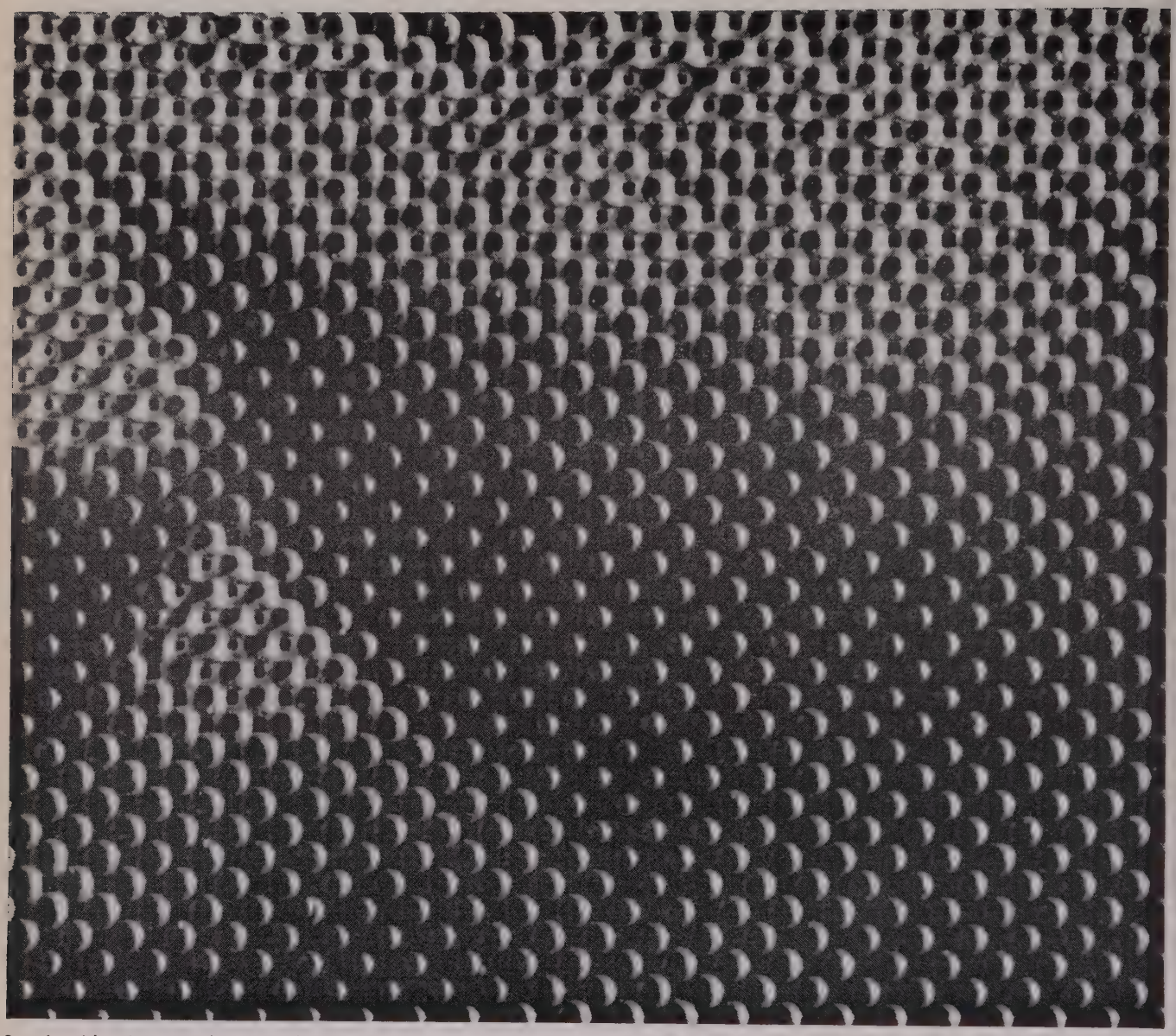

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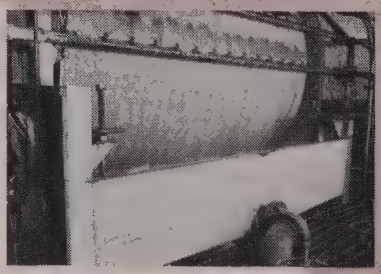

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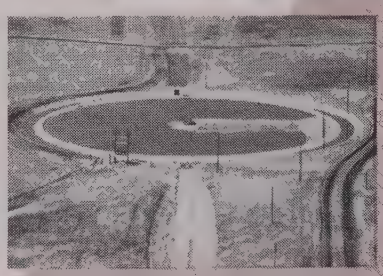

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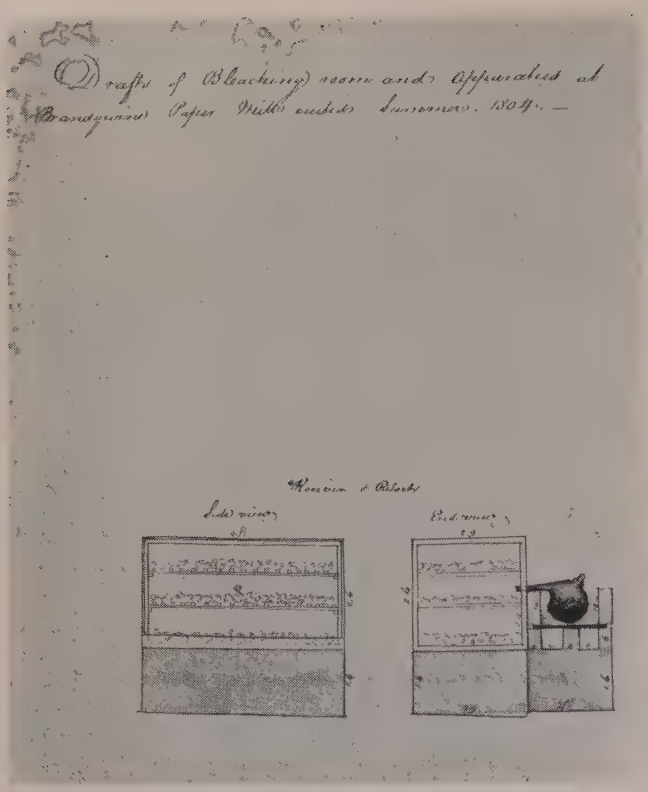
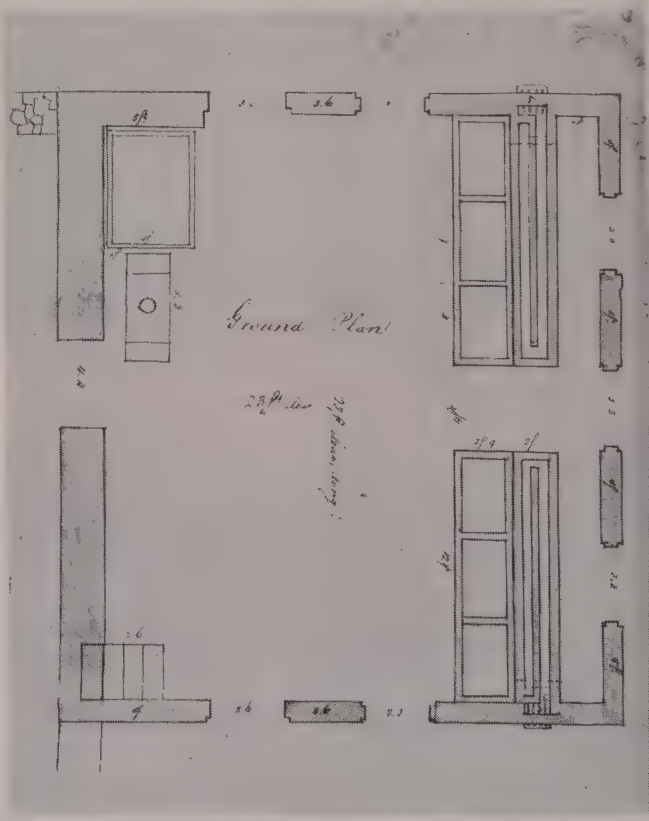


"Elevation" of equipment for chlorine bleaching installed at Gilpin mills in 1804. Probably drawn by Thomas Gilpin

consideration therefore, to teach the said Laurence Greatrake the art of bleaching Rags, Pulp or Paper agreeably to the privileges of a patent under the Seal of the United States dated the 14 of December 1798 granting to Cyrus Austin the exclusive right in said art agreeable thereto for fourteen years from that date an assignment whereof was made for the middle of Southern States to the said William Stidolph by the said Cyrus Austin the 13th February 1801—

"Now be it known that I the said William Stidolph for and in consideration of the said sum of five hundred dollars now paid me by the said Laurence Greatrake do hereby grant and assign unto him the compleat free use and priviledge of the rights liberties and advantages of the said Patent for bleaching Rags and Paper for the use of the Brandywine Paper Mill of Copartnership of Thomas Gilpin, Esq. and also to the said Laurence Greatrake at whatever place he may conduct the business of papermaking in America and which Said Art is expressed in the Patent in the words: to wit¶¶

"Whereas the method practised in England of applying the oxiginated muriatic acid for the purification of Rags and other substances used in the manufacture of Paper appeared to me capable of very great improvement in the composition and process. I set myself to a course of study and experiment and with great labor diligence and expense have discovered and perfected a method of applying the oxiginated muriatic acid to the manufacture of paper cheaper more expeditious and effectual than has been heretofore practised and known . . . and this method of Bleaching heretofore only applied to the unwrought material for paper is not only by my improvement rendered more expeditious cheap and perfect but may be applied with equal success to the bleaching perfecting and purifying paper itself containing in it any of the coloring or imperfection of the material wherewith paper is made . . . now know Ye that I Cyrus Austin of the County of Burlington State of New Jersey Paper Maker in order to obtain a patent right for the said valuable discovery and improvement in the art of bleaching the materials for paper and paper itself, do hereby make known and describe my before mentioned improvement in the following specification, that is to say—Take Rags colored or not of Cotton, Linnen, Hemp, or any other material used in making paper, wash and beat them until they are reduced to pulp, then take the material and press the water out until the quantity remaining is reduced to about the weight of the rags, then spread the material thinly on one or more frames or layers and place the frames at a small distance apart in your receiver bleaching machine or vessel which may be made of any shape or size and of any substance capable of retaining the rarified air and which is devoid of oil or metal and not subject to be affected by the Oxigene or acid . . . Having then closed the receiver make one or more holes in it for the purpose of receiving the end or mouth of your retort or retorts . . . Then to bleach 20 or 25 pounds of material take of Manganese 10 ounces Marine salt 16 ounces and mix them well previously to your putting them into your retort, when these are well mixed and put into the retort add to the mixture 30 ounces sulphuric or vitriolic acid and when your retort which for this quantity should not be less than of two gallons, is charged, insert the mouth or end in the receiver and close it . . . The number of retorts depends on the size of the receiver and the quantity of materials to be bleached. They should be kept in warm water or otherwise sufficiently warmed . . . the bleaching will then commence;. . .after the retorts have been thus applied about 4 hours take them out and into each retort put a pint of warm water with about 2 oz. of nitre disolved in it, shake this solution together with the ingredients remaining in the retorts which being again applied to the



"Plan" of room for chlorine bleaching at Gilpin mills in 1804

¶¶ The following is the only known draft of the U. S. patent of Cyrus Austin for bleaching rags and paper, granted in 1798. An inquiry to the Patent Office resulted in ". . .Be advised this office has no printed copies of patent issued to Cyrus Austin, Dec. 14, 1798, also no records are available from which we could reproduce. In all probability all records were lost in the fire." That the patent was actually granted is proved by the fact that in a "List of Patents that have been taken out of the office of the Secretary of State from July 1790, specifying the subject of the patents with their dates, and the names of the Patentees," printed in Vol. I of "The Emporium of Arts and Sciences," Philadelphia, 1812, there appears under 1798 the following entry: "Cyrus Austin, Dec. 14, improvement in manufacturing paper."

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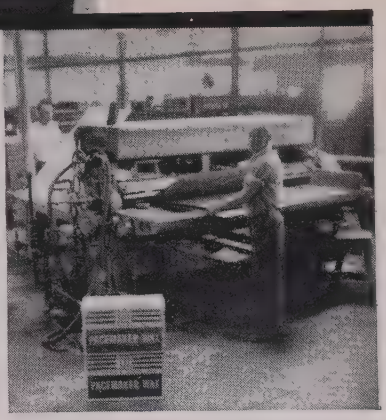

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"Elevation" of west end of the bleaching room at Gilpin mills in 1804

receiver for about 3 or 4 hours your material will be sufficiently bleached; then take it out and having dipped and washed it in water to take out the acid it will be fit for use. . .The foregoing proportions being observed, the effect will be the same upon any given quantity of material provided the ingredients are good and the apparatus in perfect order, if there should be any defect in the ingredients or apparatus the operation must be repeated until the bleaching is perfect . . . always observing that dyed materials will require a larger proportion of the Composition than rags or material not artificially colored . . . The following is my method of bleaching paper. . . the Paper to be bleached having gone thro the several operations used in making paper, press it until the water remaining in it is about the weight of the paper, then spread the paper about half a quire thick over the pulp or over layers or frames in the receivers and apply the retorts as before in bleaching Rags; when bleached proceed to finish it in the usual manner.***

"Provided however that the said Laurence Greatrake nor any of his partners of the said firm of Thomas Gilpin and Company shall instruct any person in the said art of Bleaching for any purpose or benefit than is heretofore granted or for the said Mill . . . under the penalty of five thousand dollars; the said obligation to continue during the term of the privilege of the said patent . . .

"Witness my hand this 28th day of January one thousand eight hundred and six.

WILLIAM STIDOLPH"

By the summer of 1804 a bleaching room and equipment for the process had been installed at the Gilpin Mill for our records include three pages of pen and ink drawings entitled, "Drafts of Bleaching Room and Apparatus at Brandywine Paper Mill Erected Summer, 1804."

The drawings indicate that a room 28 by 23 ft. was erected for the bleaching operation. The east side of the room contained the actual bleaching apparatus itself. There were two bleaching units 12 ft. long. Each unit consisted of three receivers 4 ft. long, 2.9 ft. wide, and 2.6 ft. high. Each receiver was fitted with three trays for holding rags or pulp, and each receiver was fed chlorine gas by one retort. The retorts were placed in a sand bath. Hot flues ran under the 12-ft. lengths of the sand baths and were apparently fired from outside the building. The west side of the room contained a large press for squeezing the rags and pulp. Equipment for washing the treated rags and pulp was also present in this part of the room. In full operation during one day with all receivers and retorts in action, about 200 lb. of rags or pulp could be bleached. This probably required the supervision of only one man. The actual costs for bleaching 100 lb. of colored rags in this bleaching room are given on one of the pages of our records, as follows:

"L. Greatrakes Estimate for bleaching
July . 21 . 1804

Cost of bleaching 100 lbs of colored Rags ascertained from the trial, during one week . . .		
3 charges Manganese	2 lbs @ 5 cents . . .	.10
3 charges Muriatic or Salt . . .	3 lbs @ 6/- p Bush W . . .	.5
3 charges Oil Vitriol	$4^1/_2$ . . . 25 cents . . .	1.12
Labor at 6 D. p Week	1 . . . (?) 15 . . .	1.15
Waste 5 pds on D 4 the value of 100 lbs of Rags . . .		.20
		2.62

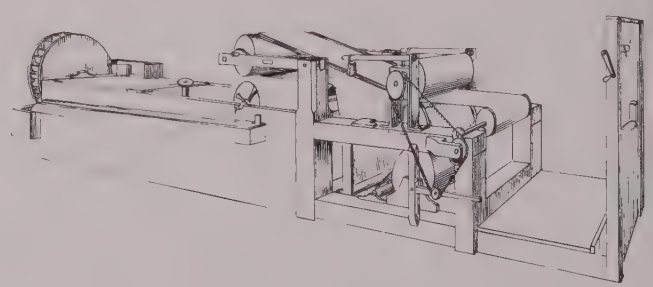
"Pulp from colored Rags, very low fifths and Sails. I value at 11 cents p. lb. . . .Pulp from, good fifths and low fourths @ 15. I have no doubt the Pulp from these may be worked $^1/_3$ D into the finest papers. . .this however remains to be proved. . . at any rate a thoughtful Steady person will be necysary to do it compleat. . .

"The labor would be no more charge for 200 lbs than for 100 lbs. . ."

Obviously this week's run and experience indicated the good possibilities of the chlorine bleaching process. Certainly the process of Cyrus Austin was used for at least 2 years by the Gilpins for the dates of the License Agreement indicate this.

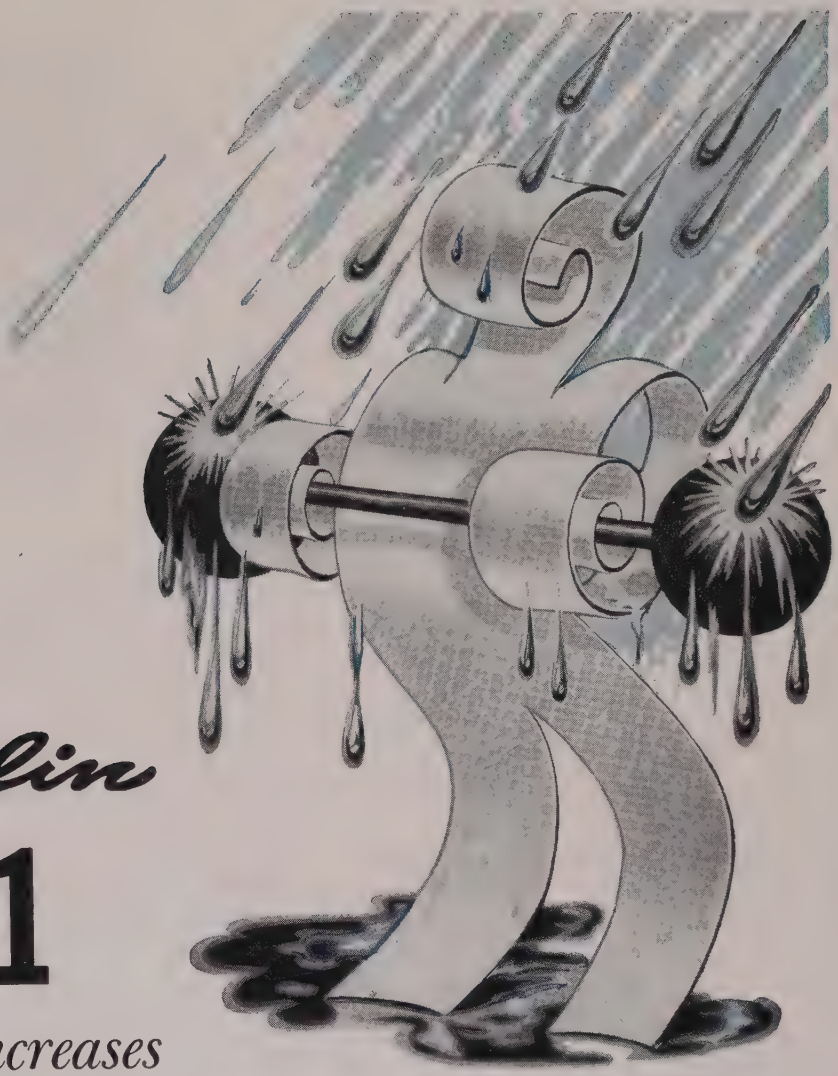
The Gilpin Mills continued to prosper. Thomas' technical ingenuity, curiosity, and desire for improvements remained unabated. By December, 1816, after long experiments, he had invented a papermaking machine. By 1817 this machine was in operation at the mill at Brandywine. This was another "first," for the Gilpins. .the first mechanical manufacture of paper in a continuous sheet in the United States (*9*).

The prosperity of the paper mill did not endure forever. In February, 1822, a great flood on the Brandywine carried its dam away, injured machinery, and damaged several buildings. In April, 1825, a fire destroyed a group of the buildings and much machinery.



The Gilpin continuous papermaking machine, 1817 (courtesy Hagley Museum)

*** It is difficult to see "invention" in Austin's patent in view of the techniques noted by Joshua Gilpin in England at about the same time. Perhaps the bleaching of the "pulp" and the addition of nitre to the retorts may have been the "Improvements in the Art." In 1798, the rules for obtaining a U. S. patent were not strict and any idea could simply be registered, and a patent would be granted by the Secretary of State. Austin's patent was the 218th American patent. It was the third American patent having to do with paper and the first concerned with bleaching and the first involving the manufacture or use of chlorine (*8*).



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RESIN 301

substantially increases

WET STRENGTH

without increasing cost

Because it is more efficient, Catalin Resin 301 . . . a modified, cationic urea-formaldehyde resin . . . can substantially upgrade wet strength with the same percentage of resin solids previously used . . . or cut resin costs by maintaining present wet strength properties with less resin solids. You gain in other ways too . . . Catalin Resin 301 is lighter in color . . . and reacts exceptionally well in the presence of dyes. Dry tensile, mullen and folding endurance is also improved.

Usable in a wide variety of bleached and unbleached pulps, Catalin Resin 301 develops about 50% of its final wet strength as it leaves the machine . . . full cure is reached within 2-3 weeks. Since wet strength is developed slowly, broke can be easily reclaimed.

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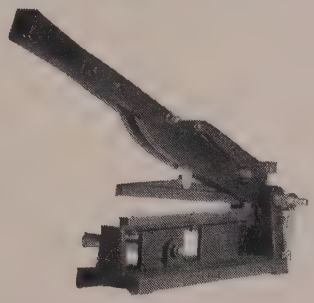
ideal for tissues, paper, paperboard, foils, plastics, light metals, etc.



The use of Thwing-Albert Precision Sample Cutters eliminates the major cause of inaccurate tests.

Strips are cut with clean, sharp edges of the exact width, parallel throughout the entire length, free from nicks and uncut or pulled fibers.

Prepares sample strips quickly and accurately.

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Hold down prevents material buckling away from, or being drawn unevenly into knives.

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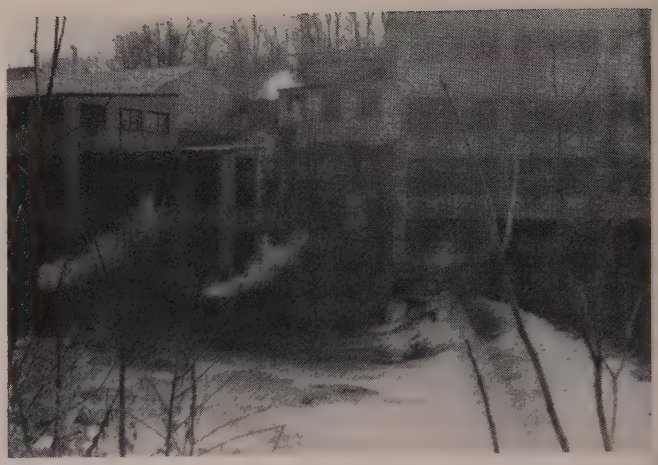

Present day view of the site of the Gilpin Paper Mills

Finally, in 1838 another flood damaged the property and equipment even more seriously than before. At this time the Gilpin brothers decided to discontinue paper manufacture. The property was sold and was refitted for the manufacture of cotton goods (*10*).

Fortunately, Weeks, in his "History of Papermaking in the United States," has furnished us with an account of the mill by a contemporaneous writer, when it was in its prime.

"Citizens and strangers often resorted to this estate for a pleasant walk and to enjoy its beauteous scenery, as well as to see the novelty and skill of mechanism, visit the wonder-working machine that could turn out an endless sheet of paper. Papermaking is too well known to need a description. Yet, as things here were on the most approved plan, and order and neatness presided, we will venture to sketch one apartment in the old mill . . . a large salle on the lower floor, where more than thirty women were seated on high stool at a long table placed before the windows, each one having a knife to pick the motes from every sheet; and they were dressed becoming their occupation, with a clean apron as smooth as if an iron had just been rubbed over it. Not a cobweb marred these white walls, nor was dust allowed to soil the floors.

"Just above this, a large and modern stone building was occupied in the same way. Many departments of the business were carried on in each of these houses. The stone house below was used for assorting and cutting rags and another stone structure for extracting colors. In this, immense kettles were fixed in furnaces built of stone that seemed immovable.

"Flat boats often conveyed paper on the water from one mill to another; but it was generally taken in wagons to the Wilmington wharves. Large quantities of bank note paper were made here. We have seen whole pieces of new silk handkerchiefs cut to mix with the rags, to designate its manufacture" (*11*).

Joshua Gilpin died at the age of 74 and left behind a big family. Thomas died in Philadelphia in his 77th year.

A visit to the spot on the Brandywine where the Gilpin Paper Mill stood reveals no marker. In fact, the spot is now occupied by one of the buildings of a great textile bleachery. A short distance up the river, however, a beautiful museum, devoted to the early industries on the Brandywine, gives a prominent place to the work of the two brothers. Our discovery of their introduction of chlorine to the papermaking industry of the United States adds additional luster to the Gilpin name.

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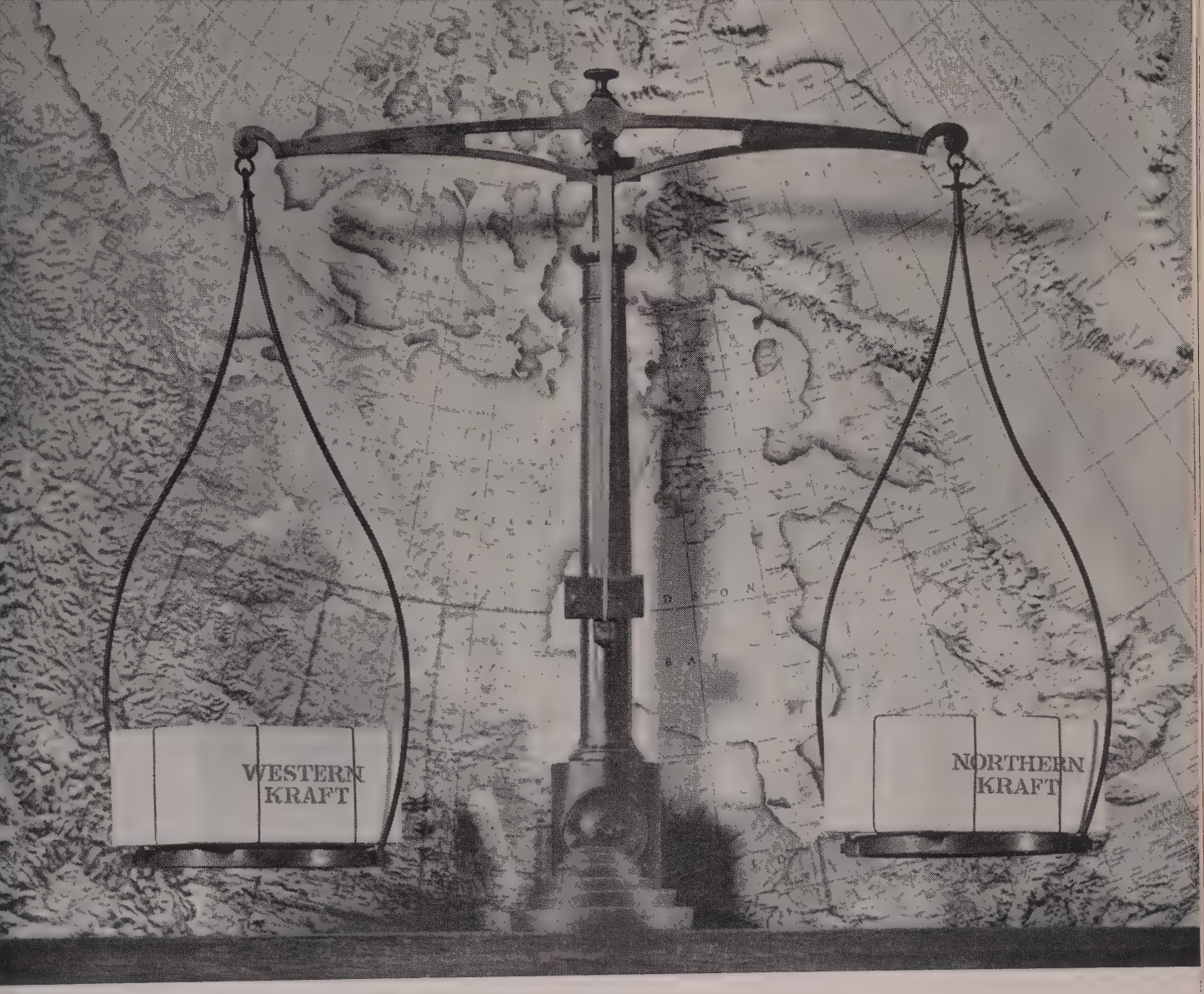
Dr. Wyndham Miles of the Army Chemical Center and Dr. Norman B. Wilkinson of the Eleutherian Mills—Hagley Foundation, have been most helpful in the preparation of this article. The author expresses his deepest thanks for their cooperation.



CELGAR KRAFT HAS THE BALANCE

The outstanding feature of Celgar Kraft pulp will be its balance of properties.

Because of the species blend in the Southern Interior of British Columbia, the Interior pulp resembles Northern Kraft pulps in many ways. It combines the outstanding tearing resistance of the West Coast fibres with the high bursting strength of Northern krafts over a wide range of freeness and in a variety of stock preparation equipment.

With this blend of qualities, Celgar Kraft will be a premium pulp in almost any field of use.

Scheduled to go on stream early in 1961, the 500-ton Celgar mill is located on the Columbia River at Castlegar, just north of the Washington border.

V4427-1

COLUMBIA PULP SALES LIMITED has been formed to distribute Celgar Kraft pulps and Columbia Cellulose sulphite pulps. Offices are located at:
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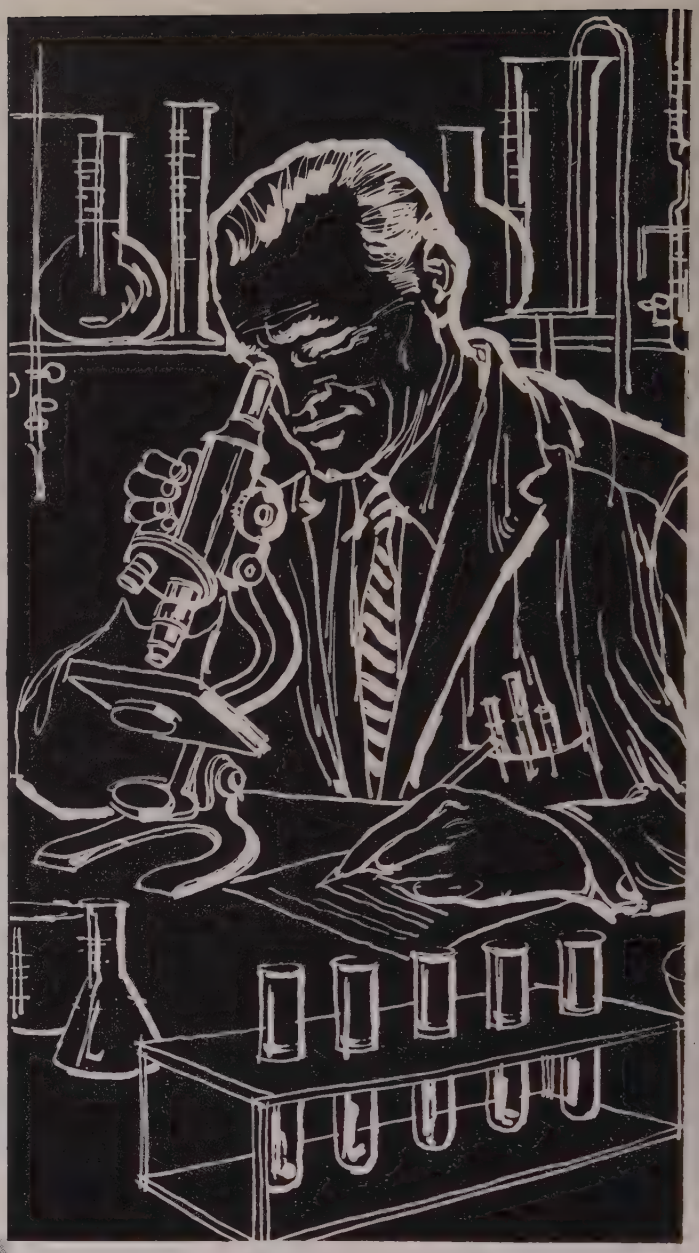
Celgar Kraft



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OK BRAND — Enzyme converting starches for sizing and coating adhesives.

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OK BRAND — A new line of corn starch derivatives for sizing and coating adhesive application.

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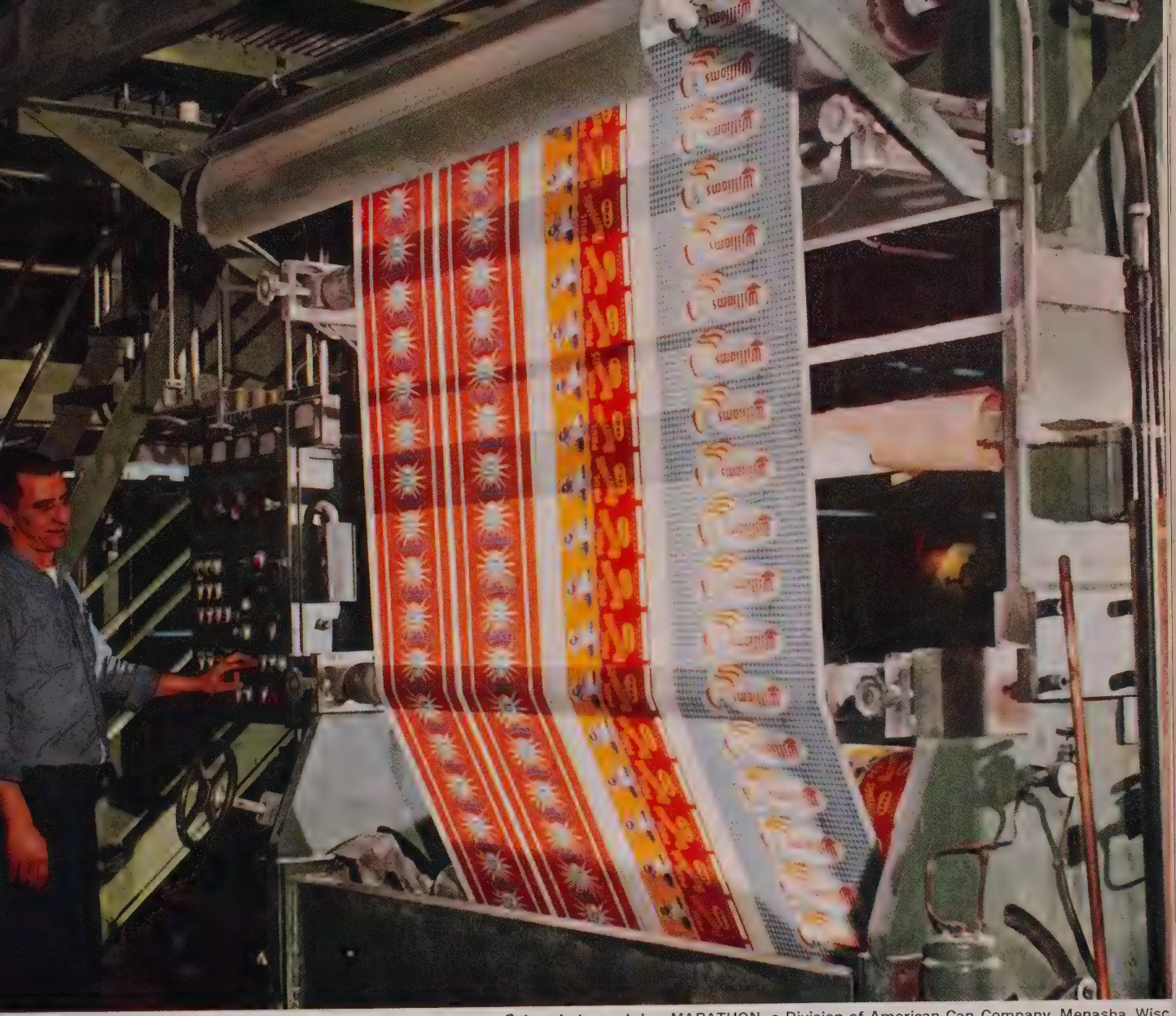

Color photograph by: MARATHON, a Division of American Can Company, Menasha, Wisc.

RHOPLEX...for fidelity in printing

Quality letterpress printing such as you see here is made possible by a combination of high quality paper and good printing technique. The paper owes its exceptional printing qualities to the coating which uses RHOPLEX all-acrylic emulsion as the binder. Whether it is bread-wrap, folding boxboard, or printing paper in general, the brilliance, detail and color fidelity of reproduction pleases both the printer and customer. Halftones print sharply by offset or letterpress without picking, varnish holdout is good, and the coating is free from objectionable odor.

Papermakers like the way RHOPLEX binders perform in on- or off-machine coatings applied by trailing-blade, air-knife, or roller-coaters. Coatings as high as 65 percent solids have good handling viscosity, help maintain maximum dryer capacity with high-solids coatings. Calendering produces unusual gloss and smoothness because RHOPLEX binders, unlike natural binders, are thermoplastic.

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RHOPLEX

"If you want your pulp to hold those extra brightness points, neutralizing with SO_2 will prevent any reversion—may even add a point or two."

James G. Todd, a technical representative for Virginia Smelting Company, answers questions on the service SO_2 offers in obtaining and holding maximum brightness of bleached chemical and semi-chemical pulps.

James G. Todd, a "Virginia" technical representative

Q Are extra brightness points important to pulp makers?

A Yes, the tendency seems to be in that direction. Paper pulp mills that were satisfied with 75 to 80 GE brightness points a few years ago are today trying hard to maintain an 85 plus brightness.

Q Can neutralizing with SO_2 help accomplish this?

A Yes. The fact that SO_2 is so easy to use and control makes it possible to adjust the *p*H to the desired level. The SO_2 converts the residual chlorine to chloride ions and at the same time neutralizes the caustic or alkaline buffers present. Free chlorine exhausted either by heat on a pulp dryer or in storage can cause reversion of the bleach. Neutralization of the alkali present allows more effective removal of cations during washing and gives a high purity pulp of low ash content.

Q But does it actually improve brightness? If so, how?

A Yes, you can actually pick up a point or so by using SO_2. The pulp usually has impurities of various kinds, such as ferric iron. Ferric iron will stain the fiber brown and is difficult to remove. SO_2 reduces the iron to the soluble ferrous state, in which it can readily be separated from the pulp by washing. In some cases lowering the iron content of the pulp raises the brightness by two points.

Q How can "Virginia" help pulp manufacturers with brightness problems?

A As you know, "Virginia" specializes in technical service. While we don't suggest we are experts in pulp making, we do have broad experience in the application of the chemicals used in pulp bleaching, especially the chemicals we supply —liquid sulfur dioxide, zinc and sodium hydrosulfite. Any pulp maker who is having difficulty in maintaining brightness can contact us and one of our technical representatives will go into his plant and give what assistance he can.

Q What specific help do you give?

A Well, we may recommend a change in the engineering of the installation if it is indicated—or a change in the way the SO_2 is used. Each plant usually has a problem that only on-the-spot analysis can lick. Sometimes the operation is satisfactory, and the problem is one of economy merely, that is, chemicals are being used excessively. A careful study may result in significant savings by cutting down on the amount. When the mill is large and the operation extensive, the savings can be very substantial.

Q Is "Virginia" technical service used frequently by the industry?

A Yes, it is in steady demand. The name "Virginia" is a familiar one to most pulp makers. One of the reasons is that "Virginia" chemicals are so widely preferred. The big majority of pulp manufacturers are using "Virginia" SO_2 as an antichlor or as a neutralizing agent because they can rely on its purity—and because of dependable service. As for our technical representatives—like myself, they are almost constantly in the field, helping manufacturers with various problems. A letter, wire or phone call to the "Virginia" offices asking for help on a problem involving SO_2, sodium or zinc hydro will bring a "Virginia" technical representative on the double.

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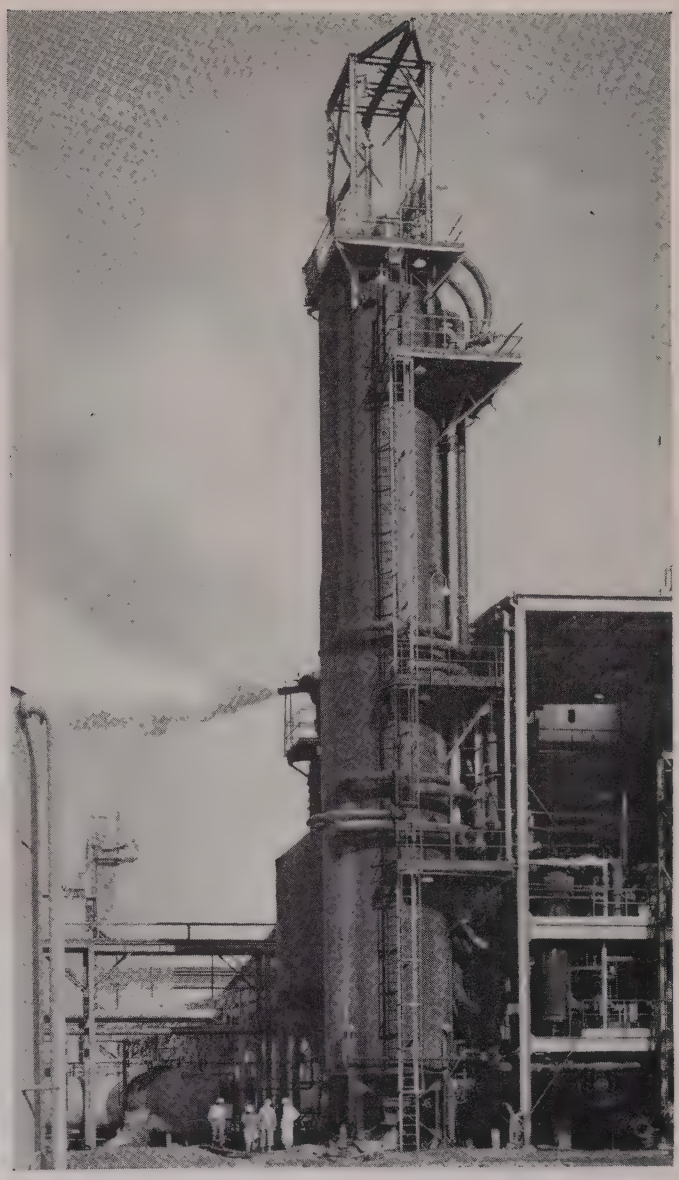

How Inconel alloy crossed out stress corrosion cracking

. . . helped boost production of continuous digester

This continuous digester is currently producing 25% *more* southern pine pulp than its rated capacity. What's more, it's a premium product that compares with the best bleached sulfate.

After going on stream two years ago, the unit ran into a serious corrosion problem . . . chloride ion stress corrosion cracking in the black liquor preheater tubes. The tubes failed within 6 months of startup (see photo on left).

After careful study of all factors, Gulf States'** engineers selected Inconel* nickel-chromjum alloy for the replacement tubes. Its high nickel content provides freedom from chloride ion stress corrosion cracking. Inconel alloy resists stress cracking, intergranular corrosion and other selective forms of attack even when subject to applied stress, welding, alternate wetting and drying, and vapor phase exposure.

Excellent results

Inconel alloy has shown outstanding resistance against pitting by the hot (335° to 345°F), pressurized (165 psi) alkaline sulfur cooking liquor passing through these tubes and by the sulfamic acid used to clean them. There is every evidence, too, that the tendency toward chloride ion stress corrosion cracking of the tubes has been eliminated by substituting Inconel alloy for original material.

In a recent test at another plant, Inconel alloy had a corrosion rate of only 0.0009 ipy in digester liquor at 344°F.

It is unusual for an alloy to have high corrosion and heat resistance and at the same time be easy to fabricate and weld. But this is true of Inconel alloy.

If you would like to know more about this useful material, write for our Technical Bulletin, T-7, "Engineering Properties of Inconel". Its 24 pages are packed with authoritative data.

*Inco trademark
**Gulf States Paper Corporation, Demopolis, Alabama

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Jones refiners

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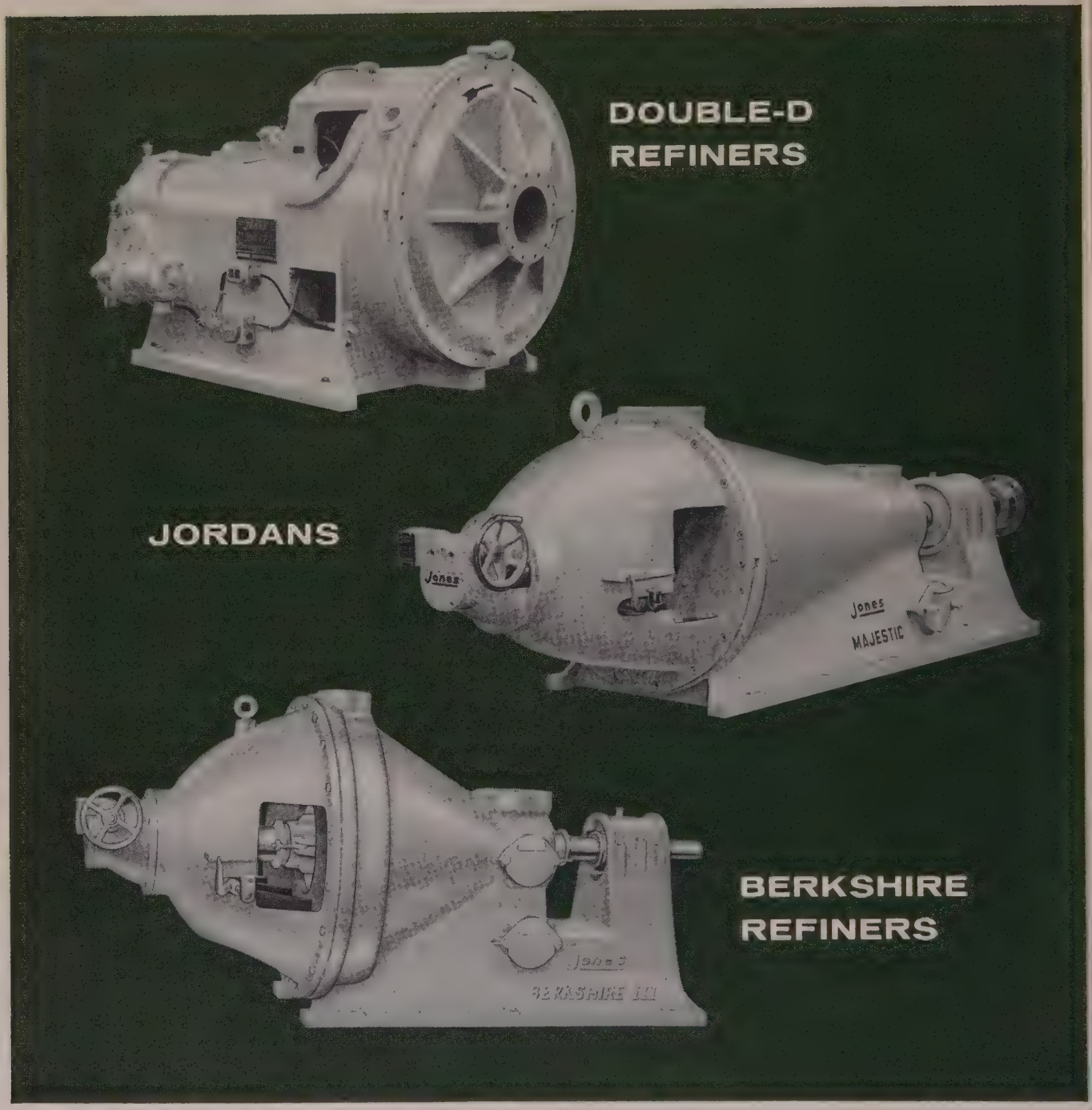

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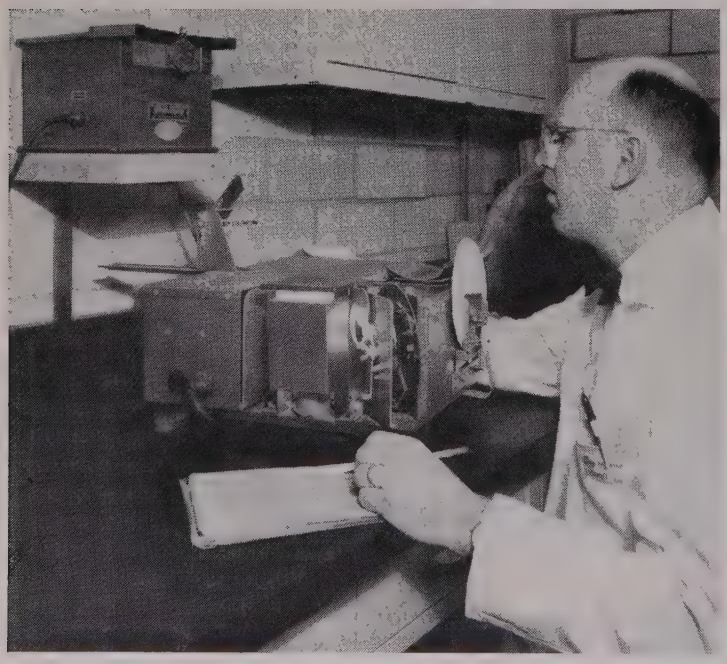
U.S.I. SERVICES THE PAPER INDUSTRY WITH TECHNICAL LAB ASSISTANCE...

IN PACKAGING — From studies such as this test of heat seal strength, U.S.I.'s Polymer Service Laboratory develops recommended procedures for all aspects of polyethylene packaging.



IN PULPING — Tech Service Engineer at U.S.I.'s laboratory-scale pulp and paper "plant" determines brightness of a hand sheet he has made from customer's pulp, on Hunter Multipurpose Reflectometer. He will also test it for tensile and bursting strengths, folding resistance.

in pulping
in converting
in packaging

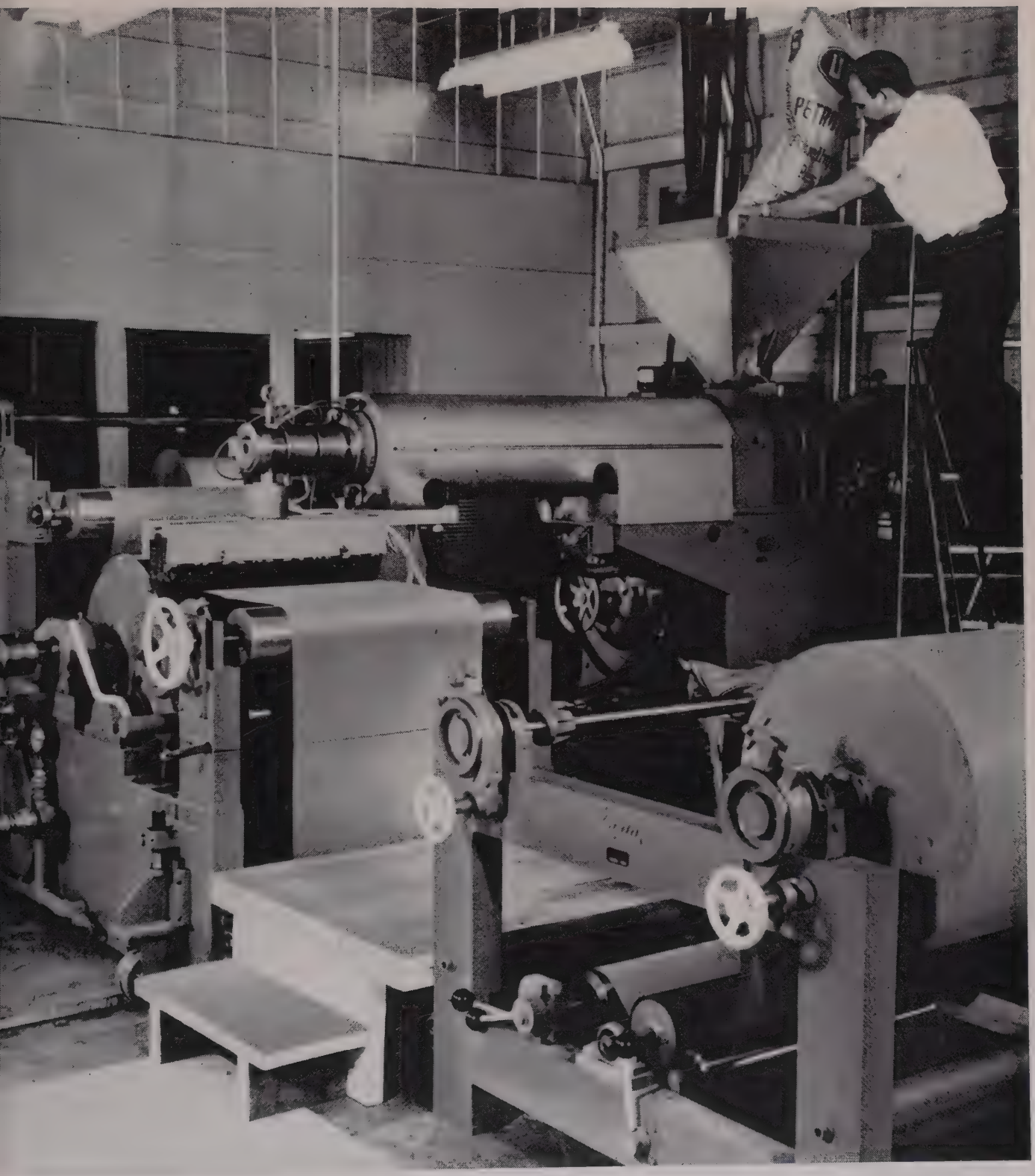
Whether you're pulping, converting or packaging paper products, U.S.I. has a laboratory and staff devoted to technical service in your field. Its job: to see that U.S.I. products for the paper industry give you the results you need in your operation.

U.S.I.'s pulp and paper laboratory — built eight years ago when U.S.I.'s Huntsville, Alabama, chlorine and caustic soda plant began operation — is a miniature paper plant, complete with auxiliary testing equipment. Here our engineers work on bleaching and assist with other applications of U.S.I.'s chlorine, caustic, ammonia, sodium peroxide . . . determine systems, techniques, types and concentrations of chemicals so that customers will know how to produce the brightest pulp with minimum fiber degradation.

Another lab at Tuscola, Illinois, is staffed with experts on polyethylene technology—including coating of paper and board, and packaging of paper products for the consumer market. They have equipment to duplicate commercial production and testing techniques . . . to tackle any problem involving an application for PETROTHENE® polyethylene resins.

A vital part of the Polymer Service Laboratory's work is development of new polyethylene paper coating and paper products packaging techniques along with design of necessary equipment.

Write or call for more information on how these services can work for you in improving your products . . . expanding your markets.



IN CONVERTING – Duplicating commercial equipment in everything but width, this coating machine at U.S.I.'s Polymer Service Laboratory is a key factor in developing new polyethylene resins for specific substrates. Latest products to come out of such work are three new PETROTHENE® resins designed for paper coating applications.

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COMPARISON OF RETENTION PROPERTIES between "Ti-Pure" HR and conventional TiO_2 is demonstrated by Dr. Harold C. Brill, Paper Section Manager, at the Du Pont Pigments Department, Technical Service Laboratory. Mixtures of chlorinated starch and pigment were prepared and then poured through filter paper. Note particles of the conventional pigment have run through the filter paper in left test tube, while the HR filtrate in the right test tube remains clear. HR has not passed through the paper. Your Pigments Representative will perform this desk-top experiment for you in your plant, if you wish.

expressly designed for wet-end addition

TI-PURE® HR

offers high one-pass retention...cuts pigment costs up to 15% in the presence of starch

Now you can cut the amount of titanium dioxide pigment added in the wet-end and still give uniform high brightness and opacity to bond, offset and other quality printing papers. The reason is new Du Pont "Ti-Pure" HR—the first titanium dioxide pigment developed expressly for papermaking.

"Ti-Pure" HR offers better one-pass retention in the presence of oxidized starches than any other pigment. (The HR stands for High Retention.) In systems without starch, HR has retention equal and sometimes superior to commonly used beater-grade pigments.

Plant run shows difference in retention

In a typical plant run, the titanium dioxide content of finished sheets showed these differences: conventional titanium dioxide plus a retention aid, 5.0%; "Ti-Pure" HR, under optimum conditions, 6.4%.

This superior retention naturally means less pigment loss to the sewer, less load on save alls. Several mills that have recently switched to "Ti-Pure" HR report savings up to 15% in pigment costs.

HR has unique properties

"Ti-Pure" HR is a water-dispersible pigment that can be added dry, or used in mills with wet slurry systems. It has outstanding suspension properties, minimizing the problem of settling in the float chambers of the metering pump. HR is not flocculated until alum or other flocculating agents are added and offers opacity and brightness, dry or waxed, similar to commonly used beater grades of anatase TiO_2.

RESULT: BETTER CONTROL over the pigment content of your papers, more uniform paper quality. Let your Du Pont Pigments Representative tell you about "Ti-Pure" HR. He'll run a demonstration for you that dramatically compares the retention qualities of HR with a standard pigment (see picture left).

E. I. du Pont de Nemours & Co. (Inc.)
Pigments Department, Wilmington 98, Delaware

TI-PURE® HR
(Titanium Dioxide Pigments)

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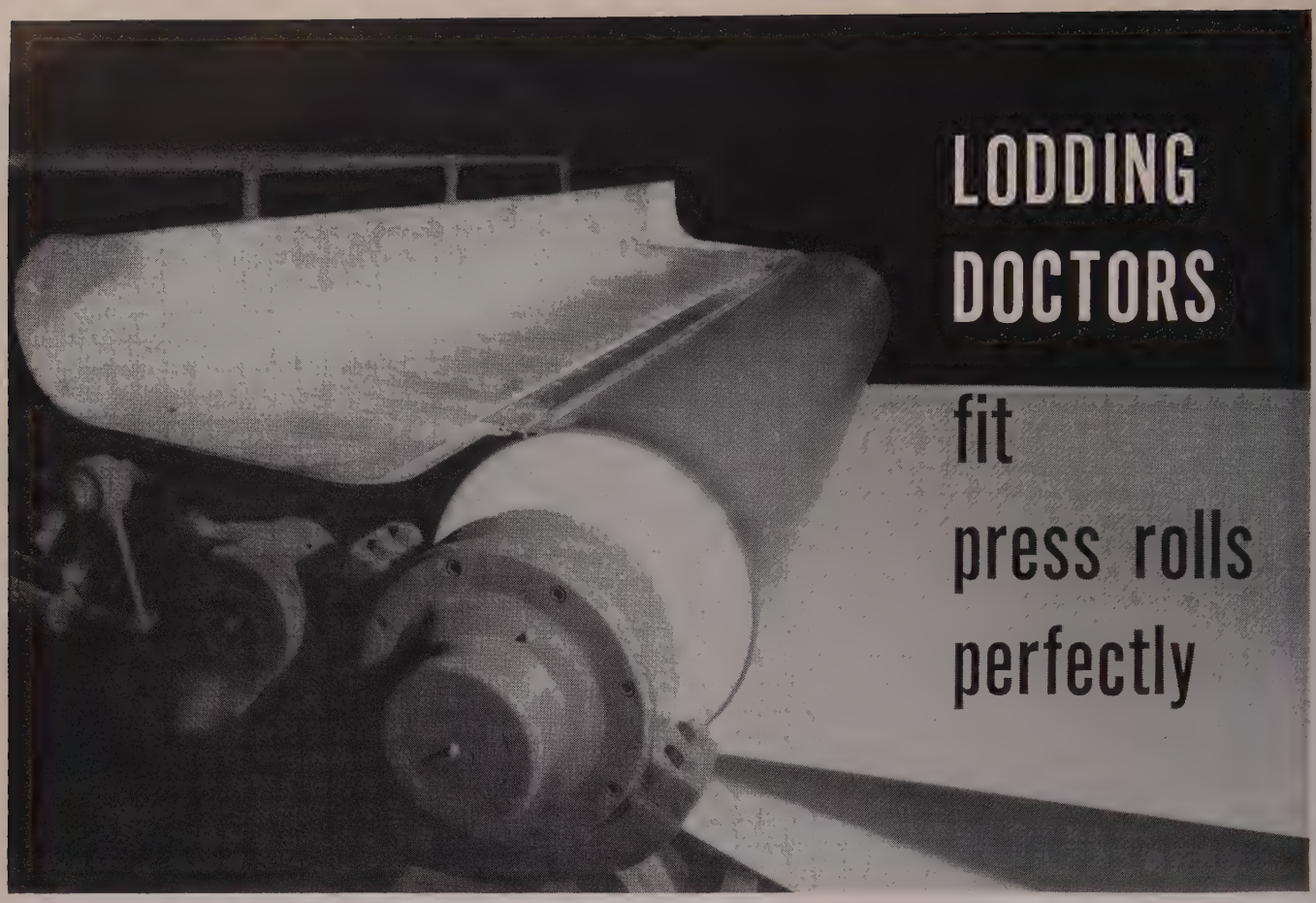
BETTER THINGS FOR BETTER LIVING
...THROUGH CHEMISTRY



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LODDING PRESS DOCTORS are recognized by their ability to remove all water from the roll. Even when running a pond, there is no leakage.

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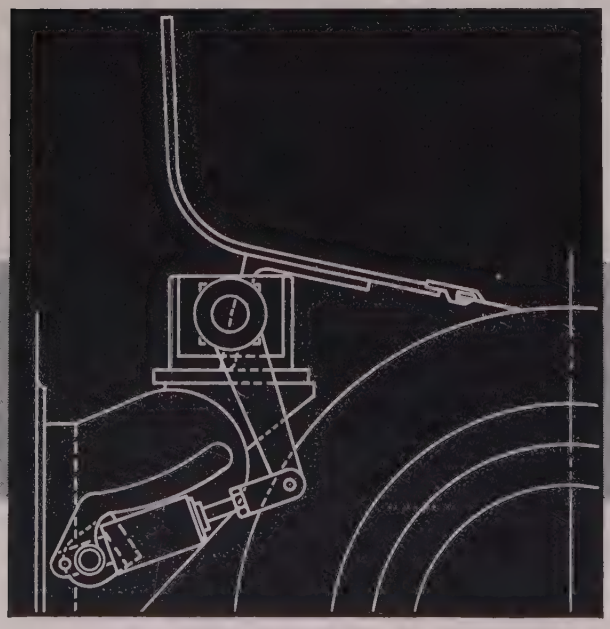

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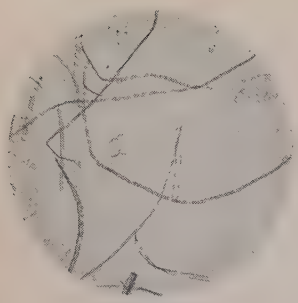
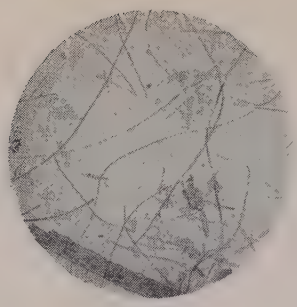
Working With The Paper Industry

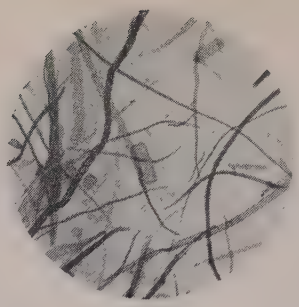
Appleton, Wisconsin



WHEAT STRAW



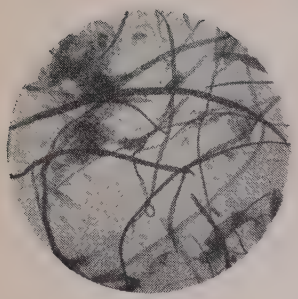
RICE STRAW



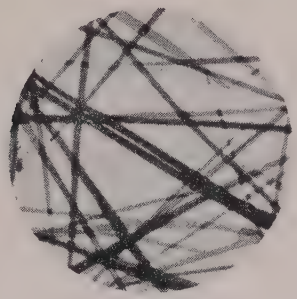
REEDS
(phragmites communis)

ELEPHANT GRASS
(before cleaning)

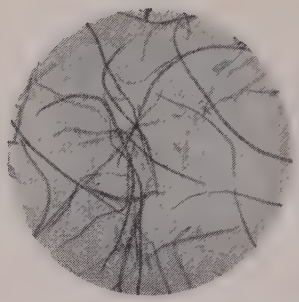
We build pulp and paper mills



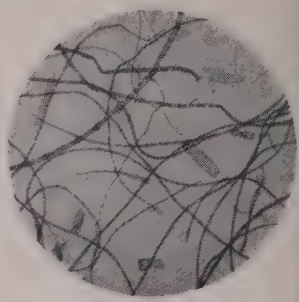
CORN STALK
(before depithing)



SUGAR CANE BAGASSE
(completely depithed)



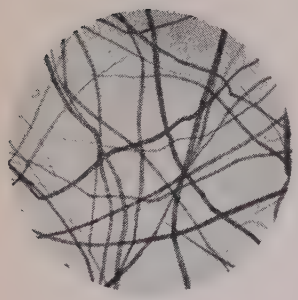
ESPARTO GRASS



BAMBOO

around the world

magnification:
approx. 35x



KENAF

MANILA HEMP

EUCALYPTUS SALIGNA

MONTEREY PINE

using these locally-abundant raw materials

Many countries have improved their economic position by making pulp and paper from locally-abundant grasses, woods and agricultural fibers. They began by having Parsons & Whittemore conduct a thorough technical and economic field survey. The selection of the proper process and equipment for use of such fibers is dependent upon many factors that can only be properly evaluated by highly-experienced personnel.

Field research is only one of Parsons & Whittemore's services. Our organization has world-wide technical, financial and machinery-manufacturing facilities that enable us to plan and supervise the designing, engineering, financing, construction and equipment of pulp and paper mills in any country having the required raw materials. We will even train local workers to operate the mill...and our branch offices will arrange for the sale of the plant's pulp and paper output on world markets. For information on any or all of these services, write to our nearest office.

THE PARSONS & WHITTEMORE / LYDDON ORGANIZATION

World leaders in the development of pulp and paper mills for the use of local fibers

18-19 Savile Row, London W.1, England

5 Rue Jean Mermoz, Paris 8°, France

250 Park Avenue, New York 17, N.Y.

This SOLVAY Technical Service specialist is measuring viscosities of pulp samples at a customer's request.

TIME ON HER HANDS

. . . *to work for you!*

In the Paper Section of SOLVAY Technical Service this young lady devotes all her time to the problems of papermen like yourself. Working with a SOLVAY field staff of industry-experienced paper experts, she's ready to give individual help to SOLVAY customers on specific matters—ranging from sample analysis to new process development. Her "office" is the nation's largest alkali laboratories.

If you would like information or technical aid in applying any of the SOLVAY® products listed here, write us. We invite you—at no obligation—to sample this rich 78-year tradition of SOLVAY quality and skill.

SOLVAY CHEMICALS FOR THE PAPER INDUSTRY:

Caustic Soda • Chlorine • Hydrogen Peroxide
Soda Ash

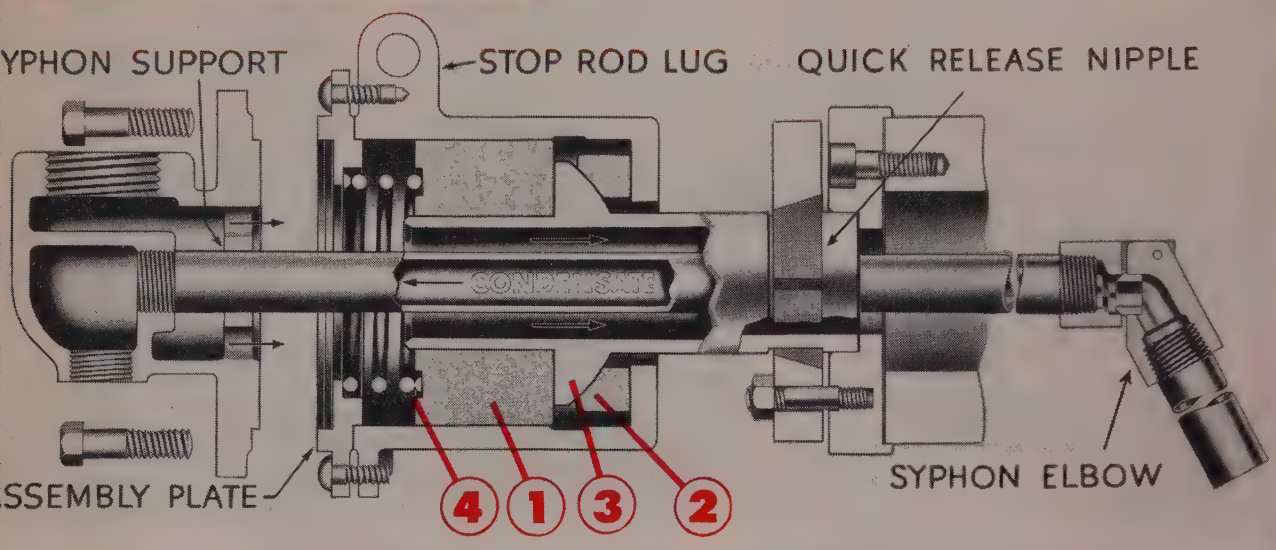
Allied Chemical

SOLVAY PROCESS DIVISION
61 Broadway, New York 6, N.Y.

SOLVAY branch offices and dealers are located in major centers from coast to coast.

SUPER Type SBP Johnson Joint with "Quick Release" Nipple

for Paper Machine Dryers . . . with STATIONARY Syphon Pipes



Only 4 Internal Parts

This simplicity of construction means fewer breeding places for trouble. The SUPER construction—which features rock-hard "Green Streak" seal rings and special Ni-Chrome plating—reduces friction and wear importantly. The "Quick Release" Nipple makes mounting, or inspection, a one-man one-wrench operation. The Syphon Elbow ends all the troubles of the unwieldy curved syphon pipes—hinges to pass right through the joint.

Like all Type S Johnson Joints, the Type SBP is completely self-supporting—needs no external supports of any kind. All in all it is a good example of why Johnson Joints are first choice in the paper industry. Type S Johnson Joints are available in sizes from ¼" through 4", for both through-flow and stationary syphon pipe applications.

FREE TRIAL—*We'll gladly furnish a pair of Johnson Joints for 90-day trial in your own mill. Write for information.*

1. **GUIDE**—Makes the joint self-supporting. It is of self-lubricating long-wearing carbon-graphite.
2. **SEAL RING**—Also of carbon-graphite. Eliminates all packing and requires no lubrication.
3. **NIPPLE**—Rotates with the roll, and seals against the ring.
4. **SPRING**—Serves for initial seating only. In operation joint is pressure-sealed.

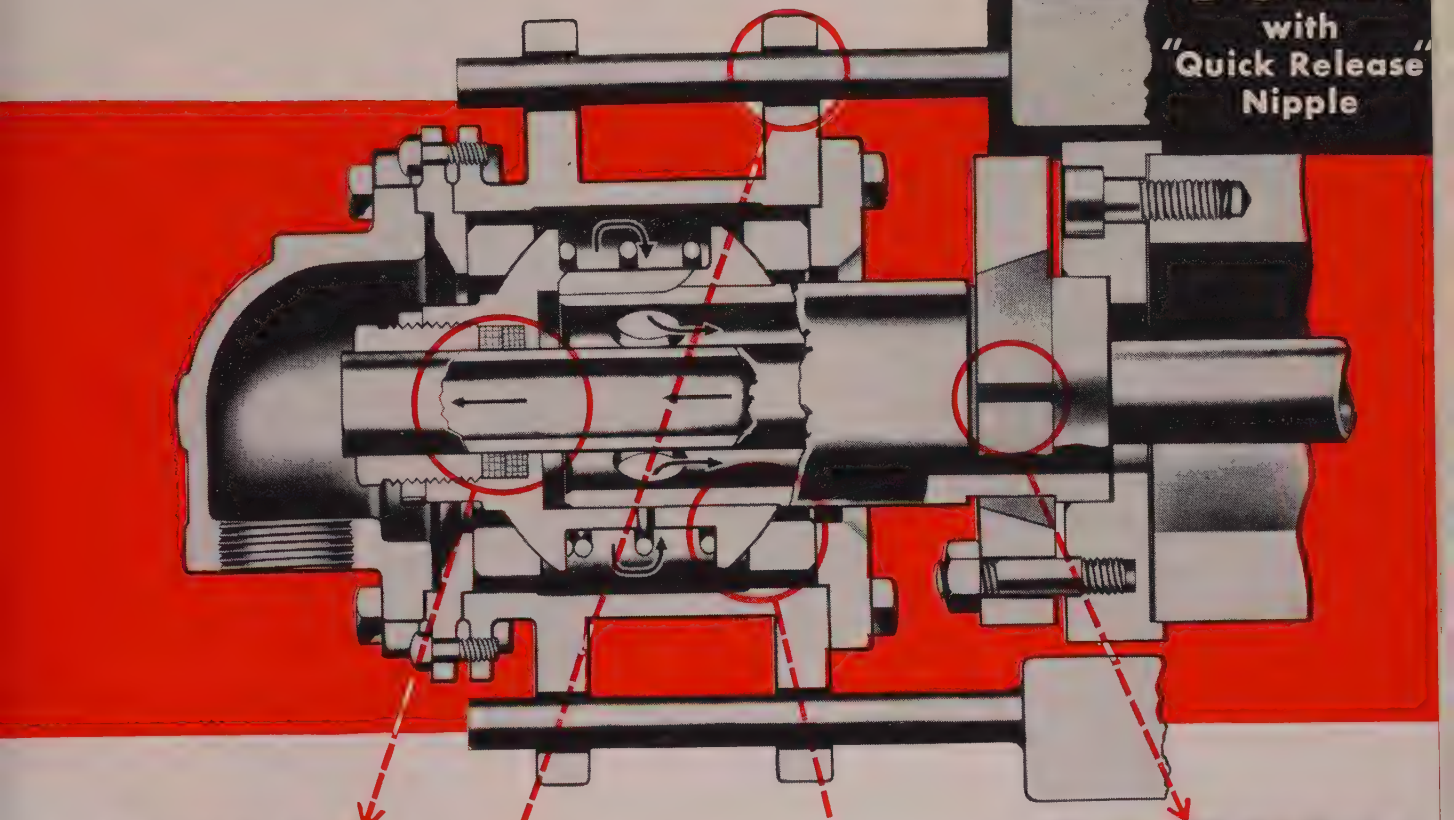
THE JOHNSON CORPORATION

843 WOOD STREET • THREE RIVERS, MICHIGAN

Rotary Pressure Joints • Direct Operated Solenoid Valves

. . . and for Paper Machine Dryers with ROTATING Syphon Pipes

SUPER Type L-N Johnson Joint with "Quick Release" Nipple



Best Design Yet

Rotating syphon pipe does not rotate in the packing; thrust collar, nipple, packing gland and syphon pipe all rotate together as a unit. Joint needs no lubrication or adjustment. Time-proved construction has only a few simple parts—a design which thwarts trouble, permits easier field servicing. Assembly plate provides ready access to syphon pipe. Type L-N Johnson Joints are available in sizes from ½" through 8".

Floating Action

Simple rod supports carry all the weight of the body and connections—permit the rotating assembly to "float" freely inside. Can be adapted for machines with open or enclosed gearing.

Easy On . . . and Off

Johnson "Quick Release" Nipple utilizes powerful wedging action to lock nipple securely to journal. You install the joint —or remove it for inspection—with just an end wrench; no danger of damaging nipple with heavy pipe wrenches.

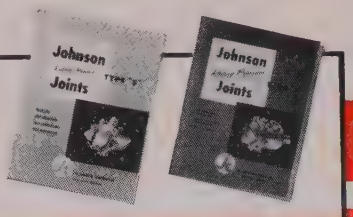
Super Construction . . . and Stamina

Teams "Green Streak" seal rings, of much harder and denser structure, with Ni-Chrome plating on wearing surfaces. Results: Considerable reduction in friction load and much longer service life.

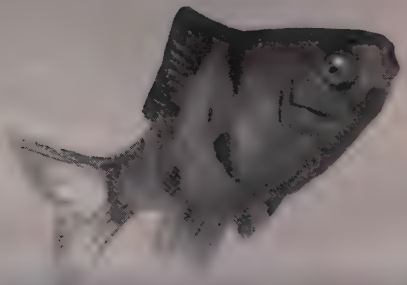
Write for Literature

Bulletin S—Johnson Joints for use with both through-flow and stationary syphon pipe applications.

Bulletin N—Johnson Joints for use with rotating syphon pipe.



this
paper
was
treated
with



SCRIPTITE* 33

*SCRIPTITE, LYTRON: Reg. U. S. Pat. Of

Monsanto Scriptite 33—a melamine resin supplied as a dry fine powder—imparts high wet strength to many paper products. It increases wet bursting strength, dry tensile strength, wet rub resistance . . . improves dry stiffness, dry mullen, folding endurance, wax pick, dimensional stability. Monsanto offers a wide range of Scriptite resins for increasing the wet strength and water resistance of paper and board. Also available are Monsanto Lytron resins, water dispersal resin polymers, for efficient paper and board coating. For complete information of Scriptite 33 and other Monsanto paper resins, write Monsanto Chemical Company, Plastics Division, Room 748, Springfield 2, Mass.

Monsanto

MONSANTO DEVELOPER IN **PLASTICS**

The Monsanto line of paper resins also includes: **SCRIPTITE 40** *urea type wet-strength resin.* **SCRIPTITE 5** *water-insoluble adhesive for paper and liner board.* **SCRIPTITE 55** *low viscosity resin for improved water resistance, we and dry rub resistance with easy handling.* **SCRIPTITE 52** *in combination with formaldehyde, gives water resistance t folding boxboard and jute liner.* **SCRIPTITE 50** *unsurpassed printability, improved surface characteristics on boxboard* **SCRIPTITE 45** *new thermosetting resin for stabilization of paper.* **LYTRON*** *water dispersal resin polymers for coating*

GOOP

agelok®

prevents galling
prevents seizing
protects valuable equipment

GOOP is the amazing new compound for ending the costly galling, seizing and resultant destruction of threaded parts.

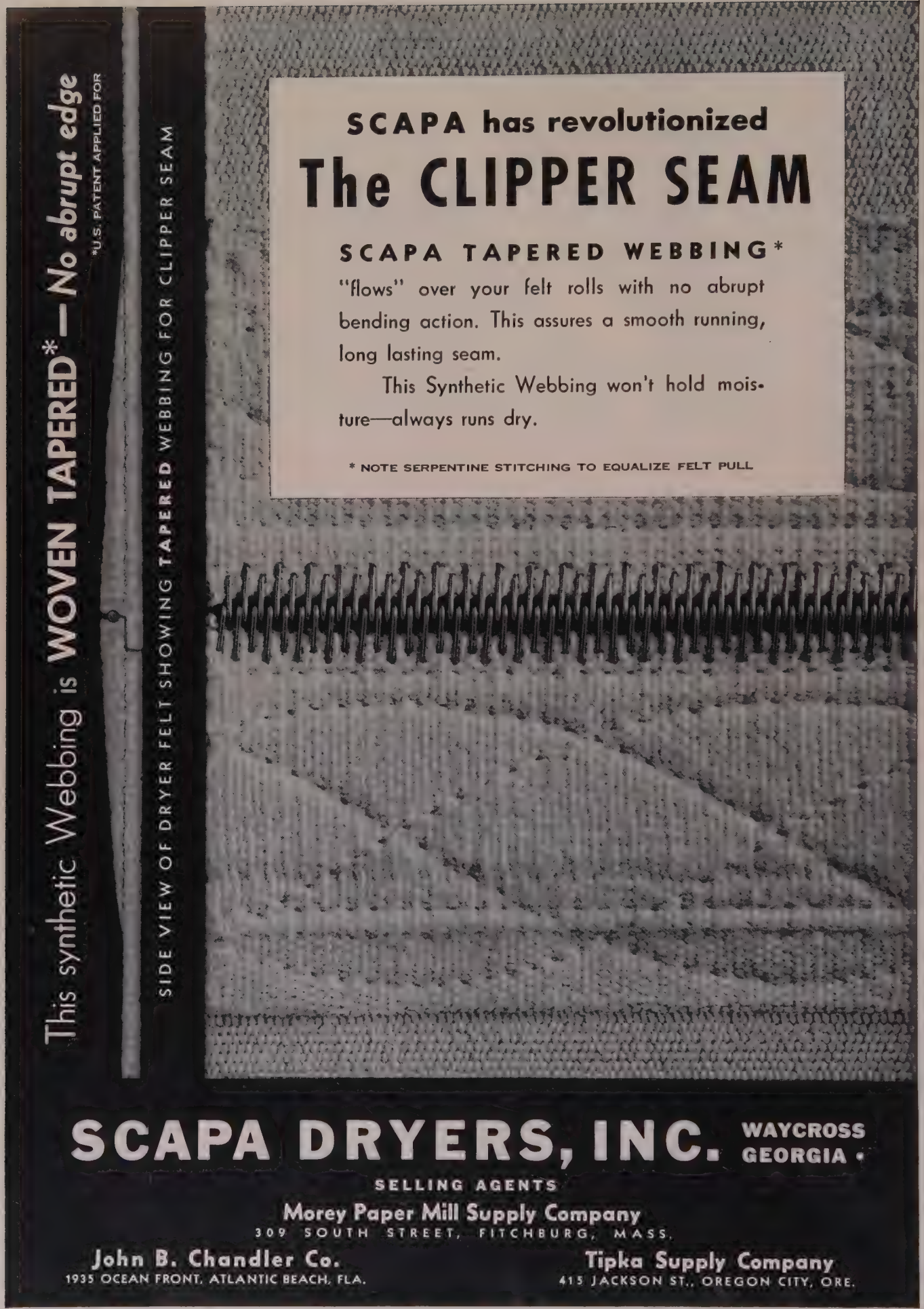
The line includes three separate products: Blue GOOP, Silver GOOP and High Purity GOOP.

Silver Goop® is formulated to prevent seizing and galling of threaded parts, regardless of applied load, at temperatures up to 2100° F. It reduces take-up torque on threaded parts. Will not drip off red-hot surfaces nor give off poisonous metal or oxide fumes at high temperatures. Resists water washout.

Blue Goop® is an anti-seize and sealing compound for use on titanium, stainless steel, steel, aluminum and high temperature alloys. Withstands temperatures up to 400° F. Impervious to water washout, most acids and all petroleum solvents.

High Purity Goop® is an anti-seize and sealing compound for titanium, stainless steel, steel, aluminum and high temperature alloys. Withstands temperatures up to 400° F. Impervious to moisture, high voltage and cyclic thermal stress. Recommended for use wherever prevention of product contamination is an important factor.

CRAWFORD FITTING COMPANY
884 East 140th Street
Cleveland 10, Ohio
Crawford Fittings (Canada) Ltd., Niagara Falls, Ontario, Canada


This synthetic Webbing is WOVEN TAPERED*— No abrupt edge
*U.S. PATENT APPLIED FOR
SIDE VIEW OF DRYER FELT SHOWING TAPERED WEBBING FOR CLIPPER SEAM
SCAPA has revolutionized
The CLIPPER SEAM
SCAPA TAPERED WEBBING*
"flows" over your felt rolls with no abrupt bending action. This assures a smooth running, long lasting seam.
This Synthetic Webbing won't hold moisture—always runs dry.
* NOTE SERPENTINE STITCHING TO EQUALIZE FELT PULL
SCAPA DRYERS, INC.
WAYCROSS GEORGIA
SELLING AGENTS
Morey Paper Mill Supply Company
309 SOUTH STREET, FITCHBURG, MASS.
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Caustic users in the industrial East, Midwest and mid-South can always depend on us to deliver promptly by the fastest possible route.

Shipments are rushed from our startegically located South Charleston, W. Va. plant by truck, tank-car or barge. Frequently we're able to get your shipment to you hours faster than producers miles closer on the map.

And you are always assured of high quality caustic in the grade and form you need, produced under modern automatic controls. Liquid grades are handled through nickel pipes, stored in lined tanks and "polish filtered" just before shipment for utmost clarity.

Why not see for yourself what we have to offer. Let us ship the next spot order you place.

CAUSTIC SODA Liquid 73%: Liquid 50%, Regular and Low-Chloride Grades: Flake, Solid and Ground
CAUSTIC POTASH 45% and 50% Liquid: Flake

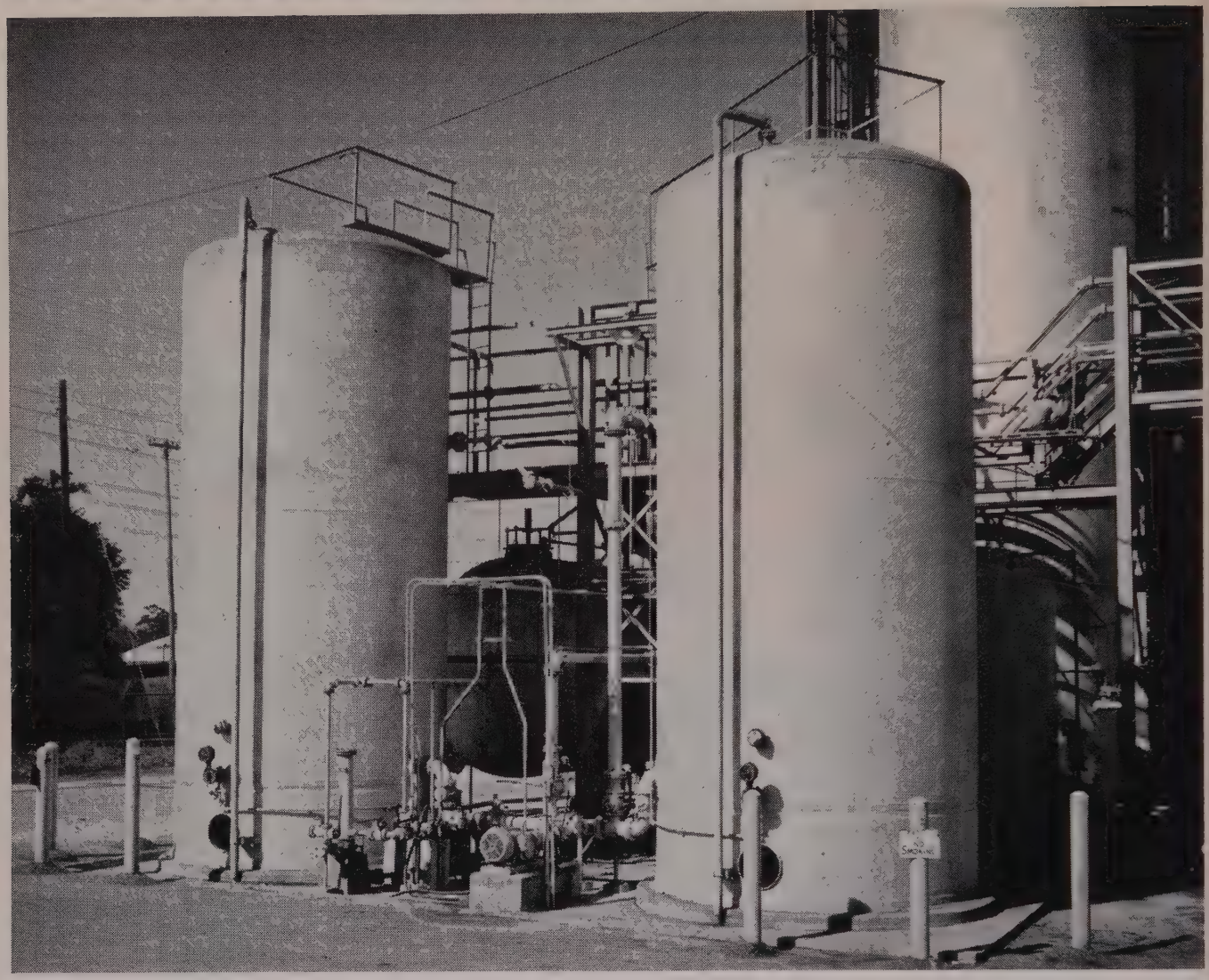
fmc
FOOD MACHINERY AND CHEMICAL CORPORATION ®

Putting Ideas to Work

FOOD MACHINERY AND CHEMICAL CORPORATION
Chlor-Alkali Division
General Sales Offices:
161 E. 42nd STREET, NEW YORK 17

THE AIRPORTICA AWARD FOR MANAGEMENT ACHIEVEMENT
FOOD MACHINERY AND CHEMICAL CORPORATION

FLUIDICS* AT WORK



Glasteel takes the bite out of corrosive chlorine dioxide at Scott Paper Company's mill in Mobile, Alabama.

How to profitably end corrosion in every phase of ClO_2 generation

If you examined these tanks for dissolving and storing sodium chlorate, you'd find no evidence of corrosion at the constantly shifting liquid-air interface.

The reason? These are Pfaudler Glasteel tanks—*steel* outside for strength, *glass* inside for corrosion resistance. And there is no rust contamination of the chlorate, which can cause troublesome "puffs."

These tanks plus towers, pumps and ClO_2 storage tanks are part of the chlorine dioxide system at Scott Paper Company in Mobile, Alabama. In operation for some 15 months now, there has been no evidence of corrosive attack in any part of the system where Glasteel has been used.

You will also find Glasteel equipment in 38 other progressive pulp mills. And, whether the Solvay or Olin Mathieson process is used, the reports are still the same: Pfaudler Glasteel turns out to be the most *economical* equipment available, in terms of cost, maintenance and service life.

With this experience and our Project Engineering service, Pfaudler offers you or your engineering firm complete plant design, procurement and installation for ClO_2 generating systems. For more information, write to our Pfaudler Division, Dept. TA-40, Rochester 3, N. Y.

PFAUDLER PERMUTIT INC.

Specialists in FLUIDICS . . . the science of fluid processes

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

Kofilm

ACETYLATED STARCH DERIVATIVE

FOR SURFACES "SMOOTH AS ICE"

An exaggeration?

Not much! Because KOFILM, our unique acetylated starch, makes a big difference in surface sizing results. Surfaces are actually smoother. With maximum print fidelity, better brightness, higher pick strengths and more uniform control of ink penetration.

KOFILM eliminates variations in viscosity and strength. It prolongs viscosity stability over extended periods of time. Performs cleanly in starch supply systems and on the paper machine. Offers high strength, more flexibility and excellent film forming properties. Improves oil resistance and wax holdout. And is an excellent pigment binder for coating applications.

KOFILM is available in a range of viscosities. Why not compare it with whatever you're now using? Your nearest National office will be glad to work with you.

National STARCHES

NATIONAL STARCH and CHEMICAL CORPORATION

750 Third Avenue, New York 17 • 3641 So. Washtenaw Avenue, Chicago 32 • 735 Battery Street, San Francisco 11

Yes, when you think about it, bright white space is what
EDGAR PAPER CLAYS are—and shipped to you
in the most convenient form—bag, bulk or slurry—rail or truck.

Step #1 in the preparation of this "bright white space" is selective mining of prime kaolin clay . . . Step #2 is water washing and fractionation with controlled viscosity and particle size to each papermaker's specification . . . Step #3—drying and large volume storage for prompt deliveries.

And—over 1,000 control tests per day to assure you highest quality Edgar clays.

Help yourself to "bright white space" in your papers.
Call M&C for ample samples, complete technical service.

EDGAR PAPER CLAYS

Edgar *from*

Minerals & Chemicals Corporation of America

5002 ESSEX TURNPIKE, MENLO PARK, N. J.

A-C® Polyethylene

CARTON COATINGS OFFER 7-WAY PROTECTION

- No more fiber scratch
- Improved scuff resistance
- Higher chemical resistance
- High grease resistance
- Better gloss
- Moisture resistance
- Reduced rub-off

If grease, moisture or fine finishes present packaging problems for your product, here's how you can pack and ship them safely *without recourse to costly carton liners:*

Incorporate A-C Polyethylene into your present carton-coating operation! It will eliminate fiber scratch and scuffing, give your cartons adequate resistance to grease, water and chemicals.

A-C Polyethylene can save you money, too. When you add it to ordinary wax coatings, *penetration is drastically reduced,* resulting in less wax consumption. For example, with straight paraffin, the normal coating weight is 7-8 lbs./1000 sq. ft. With addition of A-C Polyethylene, *it is frequently reduced to 3-5 lbs./1000 sq. ft. with superior protection!*

Write for literature, free samples. Free samples and technical data are now ready for your evaluation. Just write us at the address below. Or ask your local Semet-Solvay representative for a demonstration in your own plant. He can show you, right on your own equipment, how A-C Polyethylene can improve your cartons, save you money at the same time! *Contact us for the names of processors in your area who make up blends of A-C Polyethylene and wax.*

Allied Chemical

SEMET-SOLVAY PETROCHEMICAL DIVISION
Dept. 573-E, 40 Rector Street, New York 6, N. Y.
National Distribution • Warehousing in Principal Cities

Bigger Sales...

- No decrease in tensile strength
- Increased cross-directional tensile strength
- No effect on colors
- Rewetting properties are unaffected

Better Production...

- Machine speeds maintained or increased
- Smoother running machines — less down time
- Will not yellow or develop odors on ageing
- Will not foam or froth in use

CELLOLUBE® Q-2

Quaternary Ammonium Paper Softener

Cellolube Q-2 softens napkins, tissue and towel stocks *without adverse effect on physical properties* — puts added "soft sell" in the finished product . . . without creating processing problems. And Cellolube Q-2 gives you wider latitude in pulp selection too! Sheets leave the doctor blade more uniformly, with a finer crepe. And machines actually run more smoothly with less down time. For a revelation in superior paper softening test Cellolube Q-2 now!

Economical Cellolube Q-2 treats tissue stock for as little as $1.33 per ton, and toweling for $3.30 per ton. Increased processing speeds may actually lower your over-all costs! Tanatex is prepared to demonstrate Cellolube Q-2 in your mill on a full scale trial. For details write, wire, phone:

TANATEX

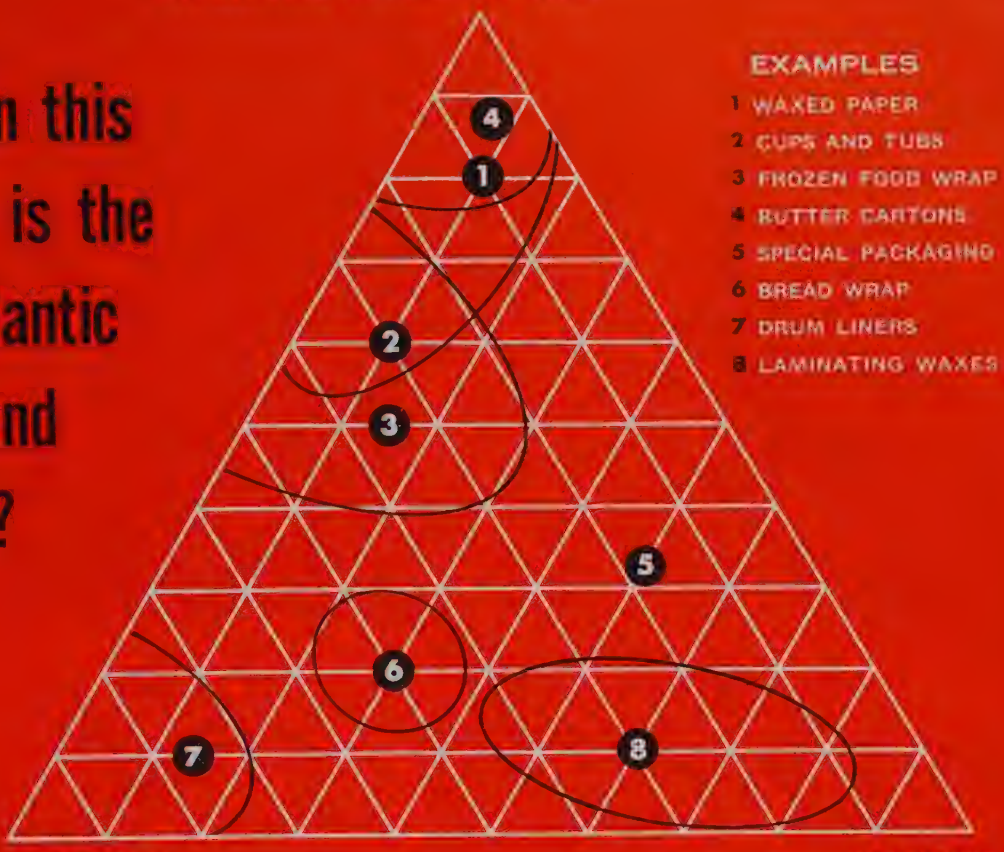
TANATEX CHEMICAL CORPORATION

Belleville Turnpike, Kearny, New Jersey
WYman 8-0732

CHEMICALS
FOR DIFFICULT PROCESSING

ATLANTIC PARAFFIN WAX

Where in this triangle is the best Atlantic wax blend for you?



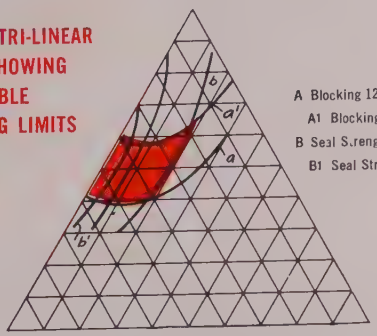
ATLANTIC MICRO-WAX ADDITIVE

Somewhere in the tri-linear chart above is a composition of high-quality waxes just right for your operations. One of the many ways in which your Atlantic Sales Engineer can serve you is to pinpoint this position after he has made a thorough study of your individual requirements.

First, he determines the proper types of waxes for protection, convenience and sales appeal in the material you convert. Precise knowledge of the values he can ascribe to each component, including any required additives, means he can locate accurately on a chart the blend composition suitable for any end use in your plant.

As an example, wax coated wrappings for frozen foods must furnish good blocking resistance for easy handling and stacking . . . strong heat seal to retain freshness and flavor . . . low moisture vapor permeability . . . and attractive high-gloss appearance. The characteristics of each component in such a coating would be plotted on the chart to form the envelope-shaped area indicated here in red. Any proportion of the waxes within this area may be satisfactory for frozen foods packaging.

TYPICAL TRI-LINEAR CHART SHOWING ACCEPTABLE BLENDING LIMITS



A Blocking 120° F
A1 Blocking 115° F
B Seal S.rength 30 gm./in.
B1 Seal Strength 15 gm./in.

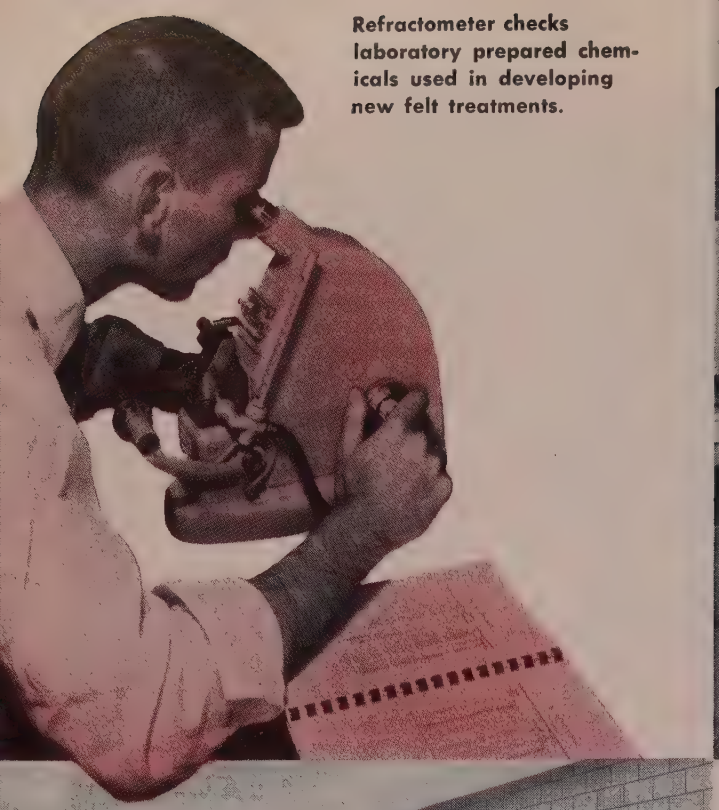
But that's only half the task. Converting equipment, methods and the packaging material used vary widely throughout the industry. It therefore requires the experience and technical knowledge of the Atlantic Sales Engineer . . . backed if necessary by Atlantic's extensive research facilities . . . to discover within the general area a composition best suited to each individual use. This basic method of exact blend determination can be applied to any field where wax blends are used.

Atlantic's technical resources and extensive knowledge of commercial wax applications are available to your firm entirely without obligation. For full information on how Atlantic can assist you in serving your customers, just call or write to your nearest Atlantic office.

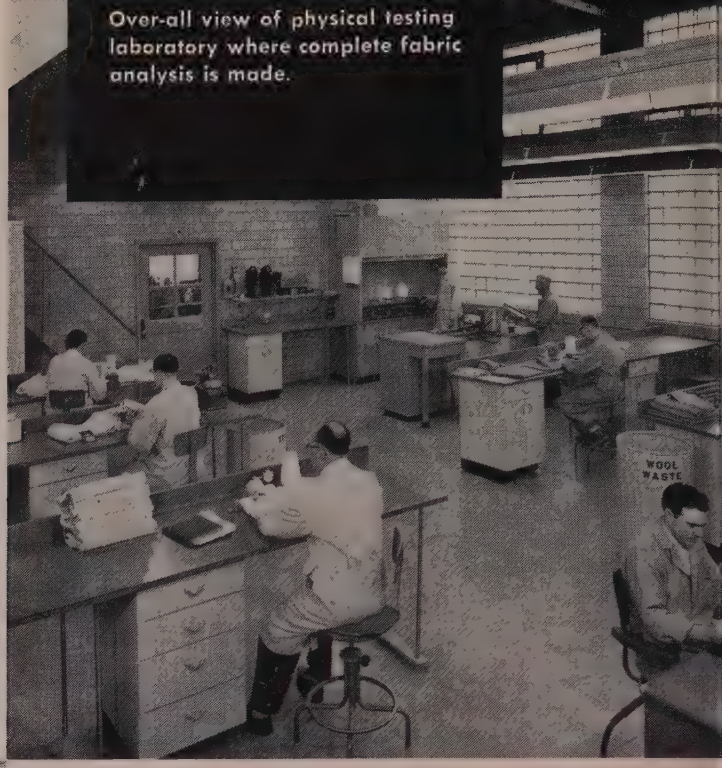
ATLANTIC OFFERS A FULL LINE OF INDUSTRIAL WAXES TO MEET EVERY CONVERTING NEED

ATLANTIC

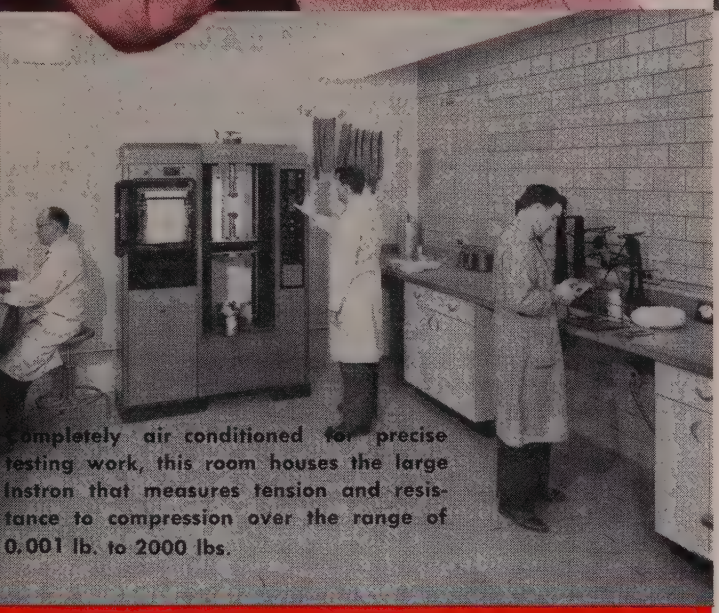
Philadelphia, Pa., 260 South Broad St. • Providence, R. I., 430 Hospital Trust Bldg. • Syracuse, N. Y., Salina and Genesee Sts. • Pittsburgh, Pa., Chamber of Commerce Bldg. • Charlotte, N. C. 1112 South Boulevard



Refractometer checks laboratory prepared chemicals used in developing new felt treatments.



Over-all view of physical testing laboratory where complete fabric analysis is made.



Completely air conditioned for precise testing work, this room houses the large Instron that measures tension and resistance to compression over the range of 0.001 lb. to 2000 lbs.

The Infra-Red Spectrophotometer "fingerprints" fibers by detecting the degree of chemical modification and helps develop new all-purpose felt treatments.

Science center of the felt industry

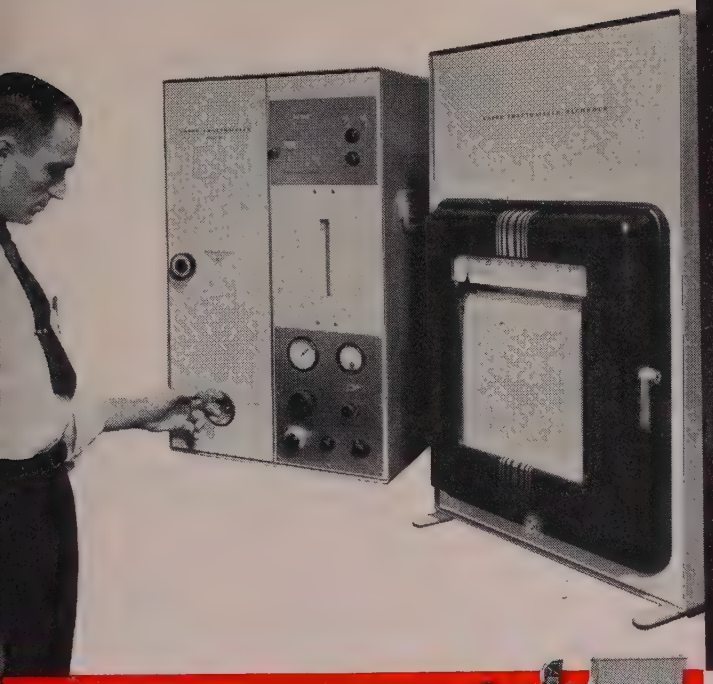
HERE HUYCK TAKES

TRAINED SCIENTISTS AND ENGINEERS
+ LATEST EQUIPMENT AND FACILITIES
+ KNOWLEDGE AND EXPERIENCE
+ DOLLARS
AND MAKES PROGRESS

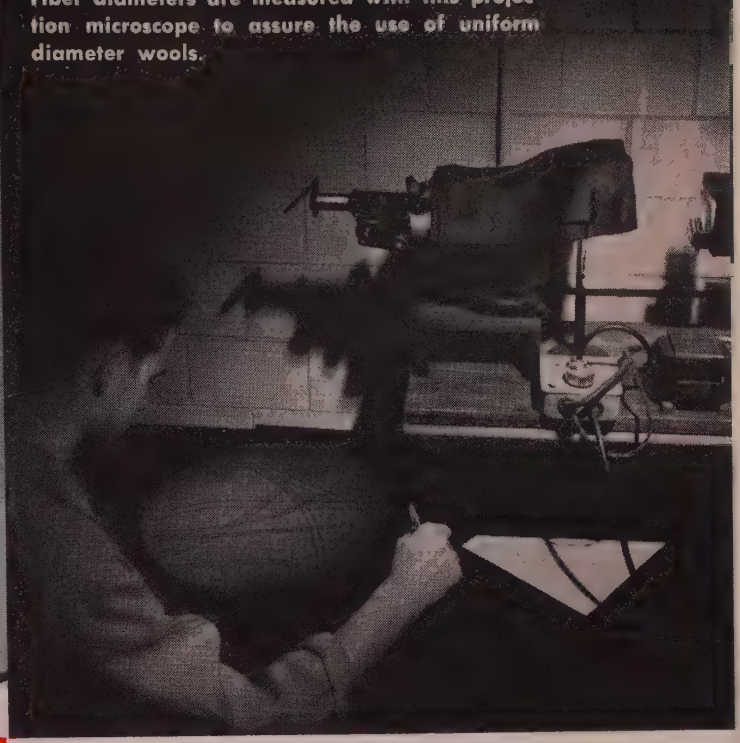
This is the basic equation for success. The millions of dollars spent each year at this Science Center results in felts that fit better, start-up faster and give longer, more trouble-free life. All-purpose 4-D Treatment and HUYVEL Process for controlling hair shedding and marking are but two of the continuing Huyck developments that mean better felt performance now and in the future.

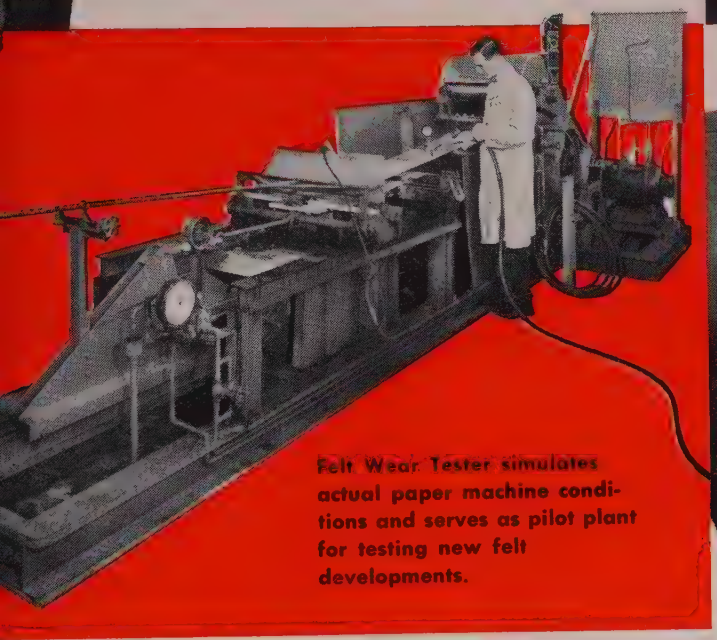
The instruments, facilities and scientists pictured are in addition to the many devoted exclusively to customer service. They represent Huyck's investment in feltmaking progress that is unsurpassed in the felt industry. You are invited to view these pictures carefully and ask your Huyck Sales and Service Engineers how each device and service can improve your felt operations.

...orming chromatographic analyses,
...rately seeks out types of felt damage.



Fiber diameters are measured with this projection microscope to assure the use of uniform diameter wools.





Felt Wear Tester simulates actual paper machine conditions and serves as pilot plant for testing new felt developments.

One of two Instrons, sensitive instruments used to measure the strength and resilience of felts, yarns and individual fibers.

HUYCK FELTS

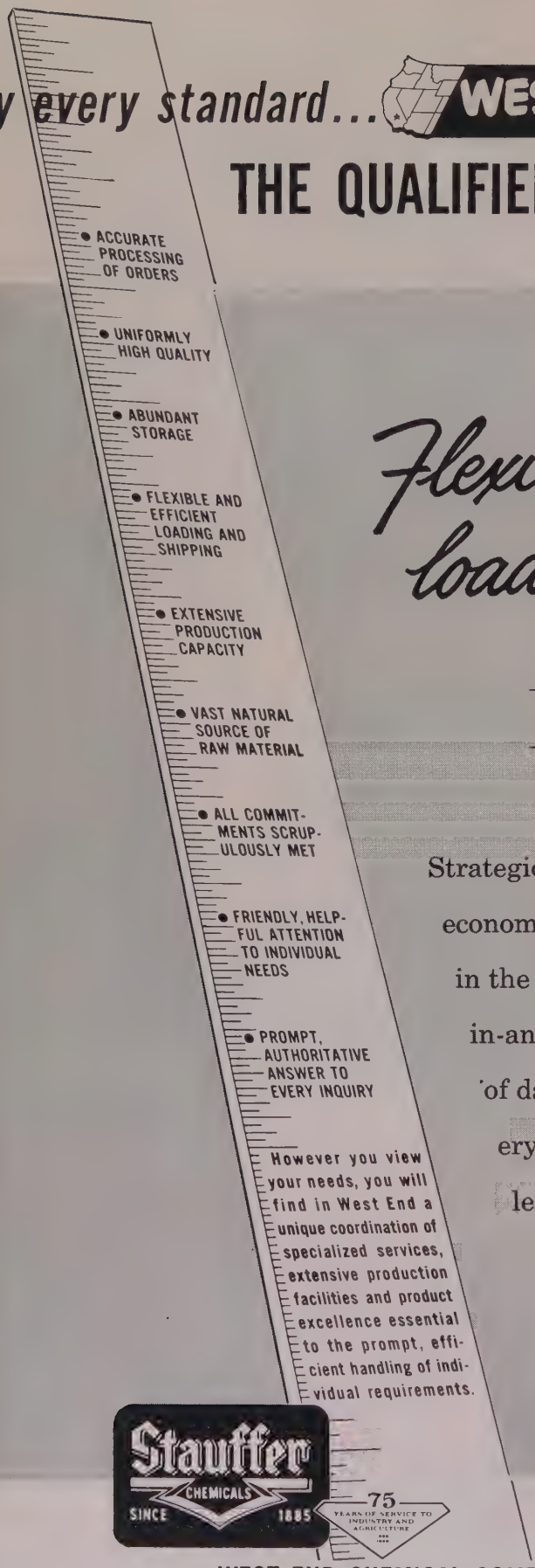
Huyck Felt Co.,
Rensselaer, N. Y.;
Aliceville, Ala.;
Division of Huyck Corporation.
In Canada: Kenwood Mills Ltd.,
Arnprior, Ontario.

NEW

HUYCK FELTS ★ INDUSTRIAL FABRICS

FIRST IN QUALITY • FIRST IN SERVICE SINCE 1870

By every standard... WEST END MEASURES UP AS THE QUALIFIED SUPPLIER OF SALT CAKE


• ACCURATE PROCESSING OF ORDERS
• UNIFORMLY HIGH QUALITY
• ABUNDANT STORAGE
• FLEXIBLE AND EFFICIENT LOADING AND SHIPPING
• EXTENSIVE PRODUCTION CAPACITY
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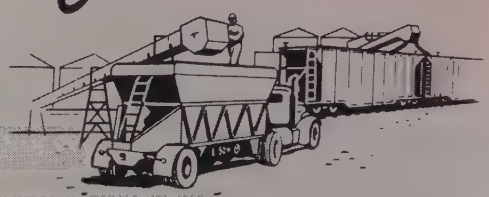

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The Influence of Selected Metal Traces on the Color and Color Stability of Purified Cotton Linters

THOMAS P. CZEPIEL

A review of the literature on brightness reversion and the reactions of cellulose suggests that salts of metals may be detrimental to high brightness in paper, either by directly imparting color or by accelerating reversion. The purpose of this investigation was to observe and interpret the effects of small amounts of selected metal salts upon the color and color stability of handsheets made from a highly purified cotton linters pulp. Salts of iron, copper, manganese, and other metals were added to slurries of pulp, and the specific absorption coefficients of reflectance pads made from the slurries were measured both before and after accelerated aging. It was found that traces of the added metal salts affected both the initial (before aging) and terminal (after aging) absorption coefficients. Although the more pronounced effect of the salts was to accelerate reversion, in the case of manganous sulfate there appeared to be significant inhibition of reversion. Conditions of temperature and moisture imposed during heat-accelerated aging were observed to affect greatly the extent of reversion as measured by the terminal absorption coefficient. Metal-induced reversion appeared to proceed in two distinct phases; the first was complete after two hours of aging, and was due to inorganic reaction products; the second was not complete even after 66 hours of aging, and was due to organic reaction products. During its second phase, metal-induced reversion was in general paralleled by hydrolytic depolymerization as measured by the intrinsic fluidity. Hydroxymethylfurfural was tentatively identified in the aqueous extracts of aged pulp, and this may be a clue to the nature of the reactions leading from cotton linters to the organic pigments.

ALTHOUGH the property of brightness and the phenomenon of brightness reversion have become increasingly important to the paper industry, technical means of effectively preventing reversion are not known. Moreover, the development of rational techniques for eliminating reversion is precluded by a lack of knowledge regarding the causes, mechanisms, and rate-controlling factors in this phenomenon.

When paper undergoes a loss of brightness as the result of either natural or accelerated aging, materials must be formed or rearranged within the pulp fibers so as to absorb visible light. The possibility exists that reversion is strictly a physical phenomenon due, for example, to the migration of colored bodies from fiber interiors to fiber surfaces, but the results of recent reversion studies point to chemical changes as the more likely cause of reversion.

Although there is little direct experimental evidence that sorbed metal salts may induce brightness reversion, occasional publications (*1–6*) have suggested such a possibility. Metal salts are known to react with certain noncellulosic components of wood pulps to yield colored substances (*7*, *8*). Moreover, metal salts have also been shown to affect the rates and products of several reactions of cellulose itself. For example, metal salts impair the permanence of paper (*9*, *10*), they accelerate the oxidation of wood pulps (*11–14*) and cotton cellulose (*15*, *16*) with hypochlorites and peroxides (*14*, *17*), and they accelerate autoxidation of alkali cellulose (*18*).

The purpose of this investigation was to observe and interpret the effect of small amounts of selected metal salts upon the brightness and brightness stability of handsheets made from a highly purified cotton linters pulp. This type of pulp was chosen in order to minimize complicating effects of lignin, hemicellulose, and other components normally found in wood pulps.

Metal salts could cause reversion in cotton linters pulp by forming inorganic pigments or by promoting the formation of organic pigments. Inorganic pigments might be formed by oxidation or hydrolysis of the metal salts, by complex formation between the salts and the cellulose or its degradation products, and by reactions of the salts and the residual, minor constituents of the plant fiber. Organic pigments might be formed from either the cellulose or the minor constituents by photolysis, pyrolysis, oxidation, or hydrolytic degradation.

Distinction between reversion caused by organic and inorganic pigments might be made by observing the extent to which the brightness of aged specimens returns to its original level when the added metal salts are removed by a dilute acid extraction. For reversion brought about by inorganic reactions, removal of the salts should restore the brightness to its original level. Any reversion brought about by irreversible organic reactions, on the other hand, would probably not be affected by removal of the metal salts.

Many metal salts, e.g., ferric sulfate, react readily with water to form slightly soluble hydroxides that are more deeply colored than the original salt. Since water will be present on the cellulose during aging, this phenomenon may be important. Moreover, hydrolysis of the salts liberates acid which could react with the linters to produce organic pigments.

If oxidation of metal salts to more highly colored compounds, e.g., ferrous to ferric salts, is a significant cause of metal-induced reversion, some measure of its importance might be gained by comparing the effects of aging in air and in nitrogen.

Since metals do not tend to form highly colored salts or complexes with cellulose or simple carbohydrates, it seems unlikely that materials of this type would contribute much color to handsheets made from cotton linters. Development of color via complex formation

THOMAS P. CZEPIEL, Graduate Student, The Institute of Paper Chemistry, Appleton, Wis.; present address, Scott Paper Co., Chester, Pa. Work performed at The Institute of Paper Chemistry.

with degradation products could conceivably occur but without knowledge of the structure of these products the importance of such complexes in reversion cannot be predicted.

Since cotton linters contain small amounts of other substances besides cellulose, a highly purified grade of linters was selected for this research in order to minimize the contribution of minor constituents to reversion.

Cellulose is subject to photolytic and pyrolytic degradation, but because accelerated aging was carried out in light-tight, sealed chambers at temperatures which did not exceed 107°C., these reactions may be disregarded as important sources of organic pigments.

In the presence of oxygen at elevated temperatures cellulose undergoes oxidation to form a variety of partially unsaturated products, but even cellulose that has been treated with an excess of powerful oxidants does not usually appear colored. On the other hand, pulps having high carbonyl contents as a result of oxidation during bleaching are generally observed to undergo reversion more easily than pulps with low carbonyl contents (*19*, *20*). This implies that reversion may be the result of additional reactions following oxidation. Since atmospheric oxygen will be the only oxidizing agent present in sufficient quantity to cause significant oxidative degradation of cotton linters, the importance of oxidation could be determined by comparing the results of aging in air and in nitrogen.

Cellulose is sensitive to acid hydrolysis because of its β-1,4-glucoside structure. Limited, random hydrolysis of cellulose would be expected to reduce the D.P. Accordingly, if hydrolysis is important, the reversion process could be followed by viscosity measurements to provide one indication of the occurrence of hydrolytic chain scission. As with oxidation, hydrolysis alone cannot produce colored materials from cellulose, but, if hydrolysis is extensive or localized enough, low molecular weight carbohydrates would be formed which, upon undergoing appropriate additional reaction, could lead to color formation. There are many possible pathways by which colored substances are formed from carbohydrates and one of the more plausible is via the furans. The detection of hydroxymethylfurfural (HMF) would indicate that at least some of the products causing reversion could be formed via the furan pathway.

EXPERIMENTAL MATERIALS AND METHODS

Cellulose

The pulp used throughout this investigation was Buckeye Cellulose Corp. acetate-grade "Cotton Linter Pulp, Type 1-AR-2000." Immediately prior to use, portions of the pulp were slushed at 1.6% consistency and soaked in a mixture of hydrochloric (0.1 *N*) and hydrofluoric (0.1 *N*) acids for about 15 hr. After being filtered and thoroughly washed with deionized water to remove all traces of acid, the pulp was used to make handsheets. After this treatment the pulp, which had contained 99.6% alpha-cellulose, held no detectable manganese or copper, approximately 4 p.p.m. iron, and less than 0.01% ash.

Water

All water used in this investigation was passed through an ion-exchange column charged with Amberlite MB-3 resin. The specific conductance of water so treated was less than 0.3×10^{-6} ohm^{-1} cm.$^{-1}$.

Metal Salt Solutions

Analytical or reagent grade salts were dissolved in deionized water to yield solutions containing approximately 0.1 g. metal per liter. Aliquots of these stock solutions were added to the pulp slurries as required.

The hydrogen ion concentration of the iron sulphate stock solutions was adjusted to pH 2.2 with sulphuric acid to prevent the formation of colloidal hydroxides which might have been filtered out during handsheet formation. Although the hydrogen ion concentration of the stock solutions varied as a result of either hydrolysis or adjustment, this variation was not reflected very greatly in the pH of the pulp slurries because not more than 20 ml. of stock solution were added to 2000 ml. of slurry. Thus, pulp slurries containing no metal salts had pH's of 5.0 to 5.5, and those containing acidified iron sulfate had pH's of 4.0 to 4.5.

Addition of Metal Salts and Handsheet Formation

The equivalent of 8 g. of oven-dry, acid-washed pulp was suspended in 2 liters of water and dispersed for 15,000 revolutions in a TAPPI Standard disintegrator. This slurry was immediately divided into two equal portions each of which was diluted to 2 liters. To each portion the equivalent of 2 mg. of a metal was added from one of the metal stock solutions. The two metal-containing slurries were again divided into equal portions and the four resulting slurries filtered separately on a Buchner funnel.

The preparation of handsheets was in accordance with TAPPI Standard T 218 m-54 with the following exceptions: The pulp slurry comprising 2 g. of oven-dry fiber and 1 liter of water was filtered on two sheets of 15-cm. filter paper instead of one to prevent the holes in the funnel from marking the handsheet. Also, after the handsheet had been formed and blown on to a single sheet of 18.5-cm. filter paper, the two sheets of 15.-cm. paper were carefully removed from the wet pad and replaced by a new standard blotter. This procedure was necessary to avoid the fuzzing of the handsheet which occurred when the 15-cm. filters were removed after pressing or drying.

After the handsheets had been dried, a disk 9.0 cm. in diameter was cut from the center of each with a steel die. The disks were accurately weighed under constant humidity conditions (50% R.H. at 70°F.) and their basis weights, W, in grams per sq. cm., calculated. The disks were then used for initial optical tests.

A minimum of four reflectance disks were made for each sample, e.g., the control or pulp treated with a metal salt, to be tested. Two were used for the determination of the absorption coefficient, and the other two were used as backing for reflectance measurements and as protective padding during aging.

Determination of the Specific Absorption Coefficient

Although the brightness of paper is normally evaluated in terms of reflectance, reflectance per se is of little fundamental value because it is not directly related to the chromophore concentration in the sheet. A more satisfactory optical property of paper is the Kubelka-Munk specific absorption coefficient, k (*21*, *22*), which

Table I. Conditioning Atmospheres and Moisture Contents of Cotton Linters Pulp

Salt	*Relative humidity, %*	*Moisture content of pulp, %*
Potassium chromate	86.5 (*25*)	11.2–11.4[b]
Sodium chloride	76.5 (*25*)	9.4–10.1[b]
.....[a]	50	6.7– 7.1[c]
.....[a]	50	5.1– 5.3[b]
Potassium acetate	22.9 (*25*)	3.9– 4.3[c]

[a] Conditioned at controlled conditions room (50% R.H. and 70°F.).
[b] Moisture gained on *sorption*.
[c] Moisture held on *desorption*.

has been shown to vary linearly with the concentration of dyestuff added to paper (*23*). If color reversion is regarded as the formation of dyestuffs in pulp, then values of k should provide a reliable means of determining how much of these materials are formed during aging.

Values of k for cotton linters pulps were determined from measurements of the reflectance, R_0, of a single reflectance disk backed by a black body, and the reflectance, R_∞, of the disk backed by three additional disks. These measurements were made on the General Electric Recording Spectrophotometer (GERS) in reference to a magnesium carbonate block.

The R_0 of the disk was measured at 457 μ for ten different points on the disk and the readings averaged. The R_∞ of the same disk was next measured at 457 μ for five different points and these readings averaged. These average reflectances (R_0 and R_∞) were corrected to the absolute scale of reflectance and used to determine the value of the product, kW (W is the basis weight in sq. cm.), from Kubelka-Munk Charts (*24*) relating R_0 and R_∞ to kW. The basis weight, W, of the disk was then divided into kW to yield the value of k in sq. cm. per gram. Values of k were determined for two disks from each sample and these values averaged to give k for the sample.

Conditioning Prior to Aging

After their initial absorption coefficients, k_0,* had been measured, the reflectance disks were conditioned in desiccators at known relative humidities in order to adjust their moisture contents to the desired levels. The salts used to maintain the relative humidities, and the moisture contents of cotton linters pulp after 24 hr. of conditioning are given in Table I. After being conditioned, the samples were quickly sealed in aging chambers.

Accelerated Aging

To avoid fiber desiccation, accelerated aging was conducted in sealed chambers having low internal volumes. Aging chambers were constructed of brass, and details of their design are shown in Fig. 1. Calculations based on a materials balance indicate that for the particular chambers used in this research, 97% or more of the initial moisture was retained if 10 or more grams of pulp containing 5.5% moisture were present in the chamber during aging. At least 10 grams of linters were placed in each chamber for all trials.

Reflectance disks were stacked up and placed in the chambers as shown. Disks were separated from the brass surfaces on top and bottom by wafers of 0.005-in. teflon. Similar wafers were used to separate the disks of different samples. All four disks for each sample were placed in the chambers, but the absorption coefficients of only the two *not* in contact with the teflon were measured.

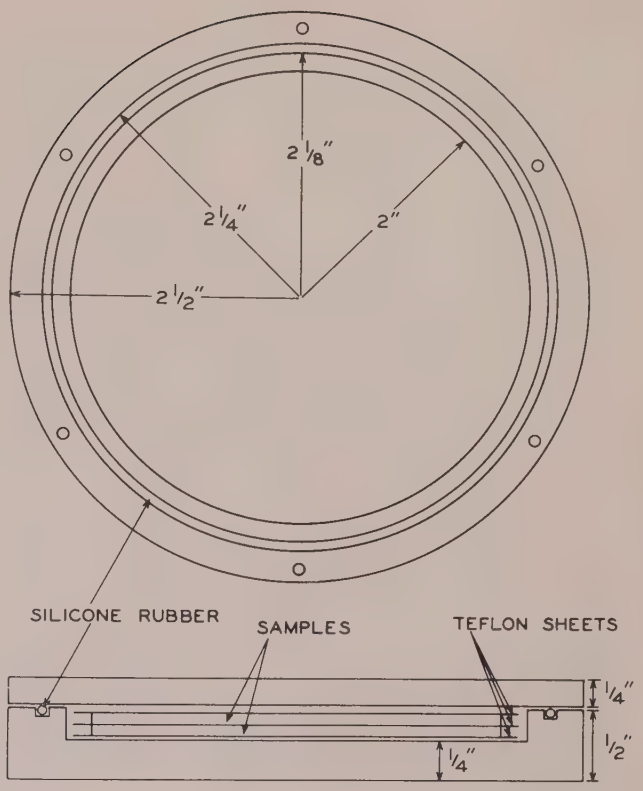


Fig. 1. Aging chambers

The oven in which the aging chambers were heated had inside dimensions of 12 × 12 × 12 in. and was fitted with a fan to reduce internal temperature gradients. The temperature of the oven cycled over a 1.5°C. range at 100°C. and completed each cycle in 2 to 3 minutes. With the aid of a thermocouple sealed in an aging chamber it was observed that the disks reached oven temperature in about 30 to 40 min.

After being heated for the desired time interval the chambers were removed from the oven, opened, and the reflectance disks removed. The absorption coefficients of the disks were then redetermined within one hour and the disks analyzed for their metal contents or their intrinsic viscosities.

Except when k was determined as a function of aging time, terminal absorption coefficients were measured after 42 hr. of aging. Unless otherwise noted the *extent of reversion* is defined as k_{42}, or the value of k after 42 hr. of aging.

Determination of Metal Traces

The amount of metals present on the cotton linters pulp was determined by first destroying the organic matter with concentrated nitric, sulfuric, and perchloric acids (*26*), and then measuring colorimetrically the amount of metals in the clear solution. Iron was determined as the orange-red complex of ferrous ion and 1,10-phenanthroline (*26*). Manganese was determined as the highly colored permanganate ion which was formed from the lower valence states by oxidation

* Subscripts given with the symbol k refer to the number of hours the sample(s) had been aged.

with ammonium persulphate in the presence of a small amount of silver catalyst (*27*). Copper was determined as the orange-brown complex of cuprous ion and 2,9 - dimethyl - 4,7 - diphenyl - 1,10 - phenanthroline (bathocuproine) (*28*).

Determination of Intrinsic Viscosity

Intrinsic viscosities, $[\eta]$, of selected samples were measured in 0.5 *M* cupriethylenediamine at a concentration of 0.20 g. cellulose per 100 ml. solution (*29*, *30*). Intrinsic fluidities $[\phi]$, were calculated according to the equation, $[\phi] = 1/[\eta]$.

EXPERIMENTAL RESULTS AND DISCUSSION

Variation of the Specific Absorption Coefficient with Wavelength

The initial absorption coefficient, k_0, of unaged samples and terminal absorption coefficient, k_{42}, of samples aged 42 hr. were measured at various wavelengths in the visible region in order to determine whether there was an optimum wavelength at which subsequent measurements of k should be made. Both k_0 and k_{42} increased as the wavelength at which they were measured was decreased, but there was no wavelength between 400 and 700 μ at which these coefficients had a maximum value. Because brightness is defined as the reflectance at 457 μ, all reflectance data for calculating absorption coefficients were measured at this wavelength.

Reproducibility of Absorption Coefficients

The reproducibility of absorption coefficients was determined in order to estimate the error in measured values of k. Data were tested by applying the student "t" distribution (*31*). For average values of R_0 the 95% confidence interval was ± 0.43 reflectance units, for the average R_∞ it was ± 0.12 reflectance units, and for the average k of a sample it was approximately $\pm 4.5\%$.

A comparison of the initial absorption coefficients from different trials indicated that the maximum coefficient of variation (standard deviation divided by the mean) for k_0 was $\pm 17\%$. A comparison of terminal absorption coefficients from different trials in which aging was conducted under nearly identical conditions indicated that the maximum coefficient of variation for k_{42} was $\pm 14\%$.

In all trials the relative effect of the metal sulfates in promoting reversion was the same, suggesting that differences in the effects of the salts were highly significant.

The Effects of Metal Salts on the Rate of Reversion

In order to determine how metals affected the rate of reversion in cotton linters pulp, the absorption coefficients of reflectance disks were determined after 2, 6, 18, 42, and 66 hr. of aging. Results of this experiment are shown in Fig. 2.

The addition of ferric sulfate increased the initial absorption coefficient, k_0, from 1.3 to 4.7 sq. cm./g. and the addition of ferrous sulphate increased k_0 to 2.1 sq. cm./g. Copper and manganese sulfates did not cause large changes in k_0.

During accelerated aging the presence of ferric sulfate greatly increased the extent of reversion for all

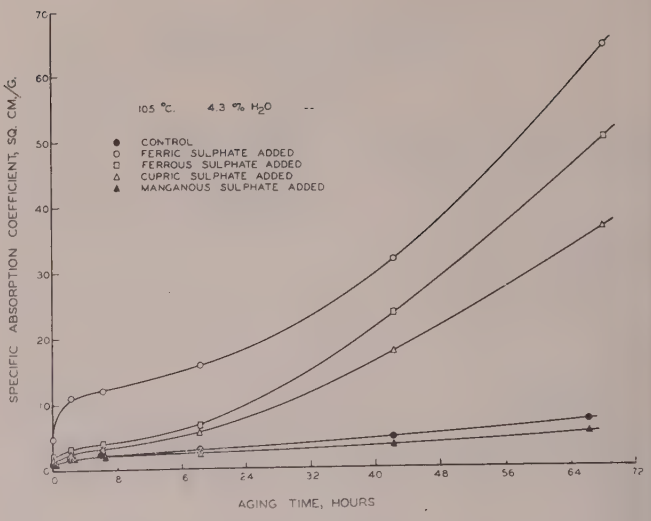


Fig. 2. Specific absorption coefficient versus aging time

aging intervals. The presence of ferrous and cupric sulphates did not cause a very great change in the extent of reversion for aging times of less than 18 hr., but did increase the discoloration occurring after longer exposure. Manganese had little effect on reversion at the shorter aging times and, quite unexpectedly, seemed to retard reversion for the longer intervals.

The rate curves in Fig. 2 suggest that metal-induced reversion, particularly with ferric sulfate, occurred in two phases. The first phase appeared to be complete after 2 hr. of aging. The second phase, during which the major portion of reversion occurred, proceeded very slowly at first, but became increasingly rapid as aging progressed and showed no signs of approaching completion even after 66 hr.

Since the rate of a chemical reaction is proportional to the concentration of its reactants (*32*), the reactants in the first phase of metal-induced reversion must have been present in limited quantities and must have been consumed within about 2 hr. It is possible that the reactants in this phase were either minor constituents of cotton linters pulp or the metal salts. The rate of the slower, second phase *increased* with aging time; therefore, its reactants were becoming more abundant with time. In view of the extreme purity of the cotton linters pulp, this suggests that the colored products were derived from the cellulose itself.

The different effects caused by the four metal ions prompted a review of the physical and chemical properties of the ions which might explain their behavior. No correlation was found between the ability of the metals to accelerate reversion and their electronic configurations, coordination tendencies, ionic dimensions, or oxidation-reduction potentials. A correlation did appear, however, between the ability of the ions to accelerate reversion and their basicities.

The basicities of metal ions can be evaluated in terms of the pH at which precipitation of the metal hydroxides or hydrous oxides begins (*33*, *34*), or in terms of the hydrolysis constants, K_{hyd}, of the metal salts. Values of the precipitation pH and K_{hyd}, for iron, copper, and manganese are shown in Table II from which it may be seen that the order of ionic *acidity* according to both criteria is:

ferric > ferrous > cupric > manganous

Table II. Properties of Metal Ions

Property	Metal ion							
	Fe^{+++}	Al^{+++}	Fe^{++}	Cu^{++}	Cd^{++}	La^{+++}	Mn^{++}	Mg^{++}
Precipitation pH (*33*)	2–3	4.0	5.5	5.4	7.5	8.2	8.5	10.5
Hydrolysis constant[a]	$1 \times 10^{-3.3}$	$1 \times 10^{-5.4}$	$1 \times 10^{-6.9}$	$1 \times 10^{-7.2}$	$1 \times 10^{-7.9}$	...	$1 \times 10^{-8.3}$	$1 \times 10^{-14.5}$
Color of hydroxide (*35*)	Red-brown	White	Green	Blue	White	...	White	White
Color of oxide (*35*)	Red-black	White	Black	Black	Brown	White	Gray	White

[a] K_{hyd} was estimated from measurements of the pH of salt solutions of concentration, c, according to the equation: $K_{hyd} = [H^+]^2/c$ (*32*).

Thus, ferric ion is the most acidic (least basic) and has the greatest effect on reversion; ferrous and cupric ions are of nearly equal, intermediate acidities and exhibit nearly equal, intermediate effects on reversion; and manganous ion is the least acidic (most basic) and has the least effect on reversion.

This correlation suggests that the products of salt hydrolysis, i.e., metal hydroxides and free acids, may play a significant role in metal-induced reversion.

Providing the salts did hydrolyze before or during aging, then the precipitated hydroxides, if colored, may have been responsible for a portion of the reversion caused by metal salts. The colors of the metal hydroxides are shown in Table II. Referring to Fig. 2 and Table II, it is interesting to note that ferric sulfate caused the greatest increase in k_0 and k_2 while ferrous and cupric sulfates had only small effects, and manganous sulfate had virtually no effect on k_0 and k_2.

In order to test the hypothesis that ionic acidity (basicity) is a factor in metal-induced reversion, the effects of aluminum, lanthanum, cadmium, and magnesium were checked. The acid-base properties of these metals are summarized in Table II.

The addition of cadmium, lanthanum, or magnesium sulfates resulted in small but detectable improvements in the color stability of cotton linters. These results are consistent with the hypothesis that the ease with which salts hydrolyze and the color of their hydroxides are associated with their ability to accelerate reversion.

The addition of aluminum sulfate appeared to accelerate reversion only slightly in spite of the fact that it has an acidity between those for ferric and ferrous iron.

The Effects of Moisture and Temperature

Moisture.—While attempting to reproduce values of the terminal absorption coefficient it was discovered that the moisture content of samples during aging had a significant effect on reversion. The moisture contents of reflectance disks were conditioned to approximately 0, 4, 7, 9, or 11%, and the disks for each moisture content sealed in separate aging chambers. All samples were aged simultaneously to cancel the effect of small temperature differences. Values of k_{42} after aging at 107°C. are shown in Fig. 3.

Some reversion occurred at all moisture levels for

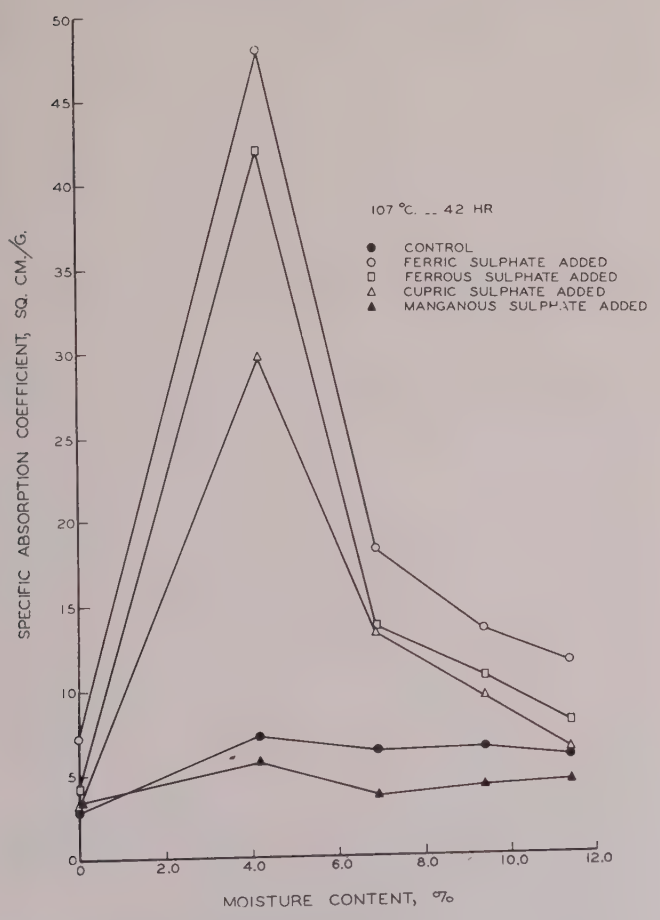


Fig. 3. Specific absorption coefficient versus moisture content

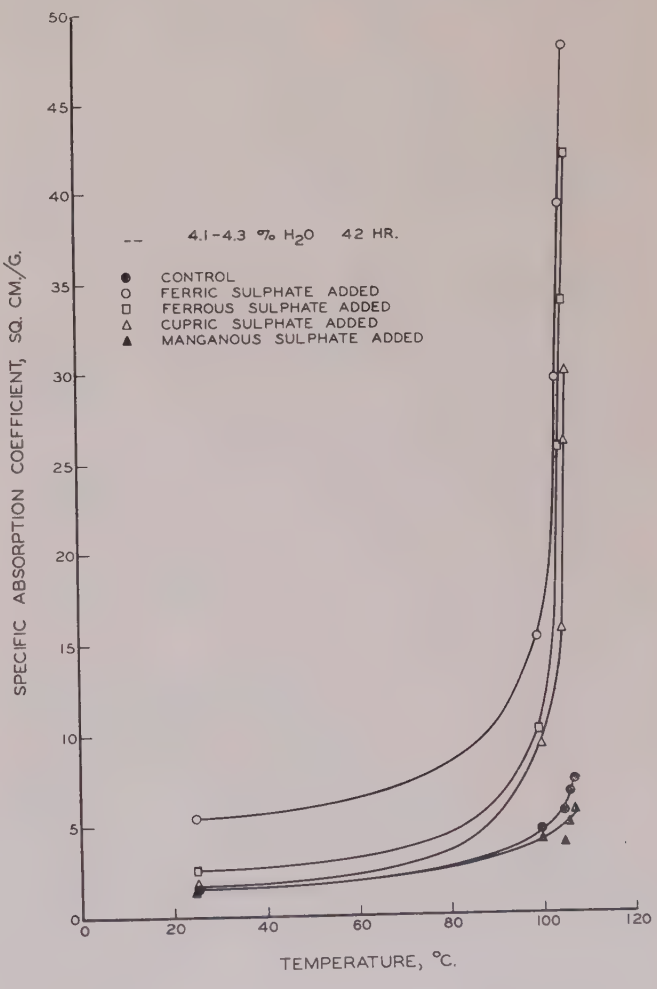


Fig. 4. Specific absorption coefficient versus temperature

Table III. Effect of Anions on Discoloration

Aging time, hr.	Anions	Specific absorption coefficient, sq. cm./g., of samples containing the following salts: Control	Ferric	Ferrous	Cupric	Manganous
0	Sulfate	1.52	4.93	2.24	1.58	1.54
0	Chloride	1.52	28.4	2.85	1.69	1.69
0	Acetate	1.48	14.6	...	1.58	1.47
42[a]	Sulfate	5.36	29.5	25.7	15.5	3.63
42	Chloride	3.82	42.1	24.3	13.8	3.29
42	Acetate	4.06	31.6	...	14.2	3.01

[a] Aged at 105°C. and 4.3% moisture.

all samples, but those containing ferric, ferrous, and cupric sulfates had an apparent maximum value of k_{42} at 4.1% moisture. A similar but much less distinct maximum was observed for the control and the sample containing manganous sulfate. The effects of moisture at temperatures below 107°C. were qualitatively similar to those indicated in Fig. 3, but the maxima were less pronounced.

Temperature. In order to estimate the effect of aging temperature on the extent of reversion, reflectance disks were conditioned to a moisture content of about 4% and aged at different temperatures. Values of k_{42} for the various temperatures are shown in Fig. 4. In this figure the points at 25°C. are for values of k_0.

From Fig. 4 the extreme temperature sensitivity of metal-induced reversion is readily apparent. The extent of reversion for samples of cotton linters containing iron and copper salts approximately *doubled* for a 5°C. increase in temperature from 100 to 105°C. Extrapolation of the curves for the sample containing manganous sulfate and the control suggests that a 10°C. change would have been required for a doubling of their extents of reversion.

These results show that variation in terminal absorption coefficients from different trials could be due to small temperature differences. In any attempt to reproduce terminal absorption coefficients accurately, temperature control would be of paramount importance.

The Effects of Anions, Metal Concentration, and Hydrogen-Ion Concentration

Anions. Since the effects of the metal salts might not have been independent of their acid radicals, the effects of sulfate, chloride, and acetate salts were compared. Reflectance disks prepared with the indicated metal salts were conditioned to a moisture content of about 4% and aged simultaneously to cancel temperature variations. The results are shown in Table III.

For manganous, cupric, and ferrous salts there were no significant differences in k_0 or k_{42}, for the three anions. This indicates that the effects observed for these salts were due specifically to the cations.

For ferric salts, on the other hand, the chloride and acetate caused larger increases in k_0 and k_{42} than the sulfate. At equal concentrations, solutions of these salts were darker than the water-white sulfate solution, and the pulp sorbed 4 to 5 times more metal from slurries containing them than the sulfate.

Metal Concentration. The amount of metal retained by handsheets prepared according to the described method from slurries containing 1 p.p.m. of metal was fairly constant. This is apparent from Table IV where the extreme and average amounts of metal retained in eight trials are noted.

Table IV. Retention of Metals by Cotton Linters

	Metal retained, microgram-atoms/g. pulp, from slurries containing the following sulfates: Ferric	Ferrous	Cupric	Manganous
Maximum	1.81	0.84	1.44	1.26
Minimum	1.04	0.45	0.82	0.70
Average[a]	1.51	0.65	1.18	0.95

[a] Each of these averages represent 11 to 18 independent measurements.

Handsheets prepared from slurries containing 0.5 and 5.0 p.p.m. of metal, retained amounts which also fell within the extremes noted in Table IV. Consequently, the extent of reversion for disks prepared from these slurries was the same as for disks prepared from slurries containing 1 p.p.m. of metal. No additional experiments were conducted to determine how metal-induced reversion might vary for metal concentration beyond this range.

Hydrogen-ion Concentration. In considering the effect of hydrogen-ion concentration on reversion, a distinction was made between the hydrogen-ion concentrations of the slurries from which reflectance disks were made, and the reflectance disks themselves.

The hydrogen-ion concentrations of pulp slurries varied from 4.0 for slurries containing acidified iron sulphates, to 5.5 for those containing either no added metals or manganous sulfate. In order to see whether this difference could be responsible for the detrimental effects noted for iron salts, reflectance disks were prepared from metal-free slurries that had been acidified to pH 4.0 with sulfuric acid, and from metal-free slurries that had not been acidified and had a pH of 5.5. These two sets of samples were conditioned to 5.2% moisture and aged at about 100°C. for 42 hr. The absorption coefficient of the unacidified sample increased from 1.42 to 4.51 sq. cm. per g. during aging, and that of the acidified sample increased from 1.44 to 3.85 sq. cm. per g. The difference between values of k_{42} for these samples is not significant, indicating that small differences in slurry pH were not alone responsible for the greater discoloration caused by iron salts.

The hydrogen-ion concentration of the reflectance disks themselves, is probably of greatest fundamental importance because it is at this concentration that aging actually occurs. In an attempt to ascertain whether the maximum amount of acid which could be released by salt hydrolysis would cause noticeable discoloration, 2.3 micromoles of sulphuric acid per gram of cotton linters were added to reflectance disks previously prepared as controls, i.e., free of added metal salts. The choice of 2.3 micromoles of acid was based on the fact that samples treated with ferric sulfate had been observed to retain, on the average, 1.5 microgram-atoms of iron per gram; and the assumption that all of the metal had been sorbed as the sulfate, and had undergone complete hydrolysis during aging.

The acid was added to the disks in a sufficient total volume (2 to 3 ml.) to wet them completely, and the disks were then air dried without being pressed so that no acid would be removed. After the k_0 of these disks had been determined, they were conditioned 24 hr. at 22.9% R.H. and aged 42 hr. together with a control and a sample containing ferric sulfate. Results of this experiment are shown in Table V.

Allowing for the discoloration (approximately 10 sq. cm. per g.) believed to be due to inorganic com-

Table V. Effect of Sulfuric Acid on Discoloration

Aging time,[a] hours	Specific absorption coefficients, sq. cm./g., of the following samples: Control	Sulfuric acid added[b]	Ferric sulphate added[c]
0	1.26	1.30	4.63
42	3.95	10.7	30.2
42[d]	3.95	10.7	~20

[a] Aged at 105°C. and 4.0% moisture.
[b] Each disk containing 2.3 micromoles of sulfuric acid per gram of linters.
[c] Each disk is estimated to have contained 1.5 microgram-atoms of iron per gram of linters.
[d] Adjusted for discoloration due to iron compounds.

pounds in samples containing ferric sulfate, the acid equivalent of 1.5 microgram-atoms of ferric iron could account for at least one half of the organic color (approximately 20 sq. cm. per g.) developed in the presence of this amount of iron.

The Contribution of Inorganic Compounds to Reversion

The following experiments were undertaken to establish the extent to which inorganic compounds contribute to the color of aged cotton linters pulp. Reflectance disks were prepared and their initial absorption coefficients and metal contents determined. Two disks from each sample were separately extracted with 125 ml. of a dilute acid mixture (0.1 *N* in hydrochloric acid and 0.1 *N* in hydrofluoric acid) on a sintered glass filter funnel for 2 to 4 min. The extracted disks were pressed and dried according to the procedure used for forming reflectance pads, and their absorption coefficients redetermined.

Two groups of four additional disks from each sample were conditioned to a moisture content of about 4% and aged. One group was aged 2 hr. and the other group 42 hr. The terminal absorption coefficients of these aged disks were measured and the disks then extracted in the same manner as the unaged samples. Absorption coefficients and metal contents of these aged and extracted samples were then redetermined.

Acid extraction of all samples which had not been aged or had been aged only 2 hr., restored their absorption coefficients to values only slightly higher than that for the unaged, metal-free control. It therefore appears that increases in k_0 and k_2 are largely due to the formation of colored metallic compounds.

The effects of acid extraction on the absorption coefficients and metal contents of samples which had been

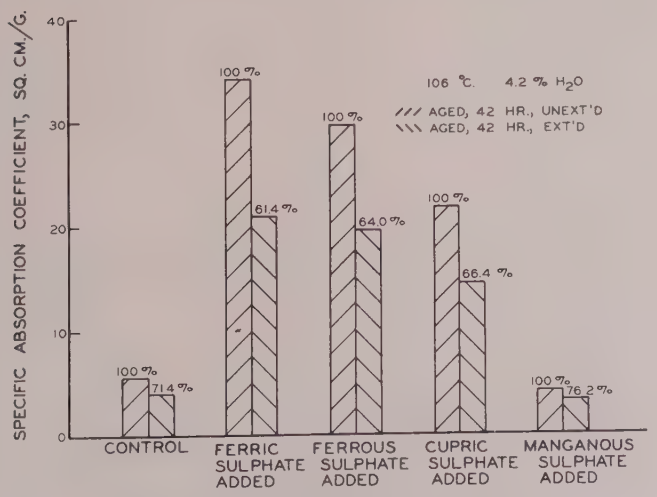


Fig. 5. Effect of acid extraction on the specific absorption coefficient of aged samples

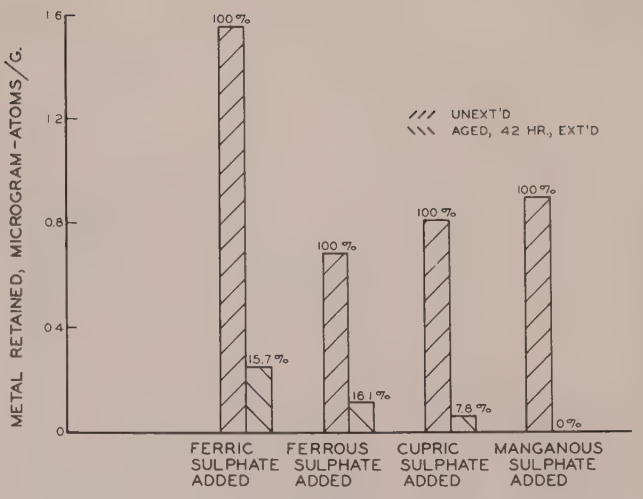


Fig. 6. Effect of acid extraction on the metal content of pulp

aged 42 hr. are shown in Figs. 5 and 6. Acid extraction reduced k_{42} only 24 to 38%, but removed 84 to 100% of the added metals. Thus, 62 to 76% of the color-producing materials were insoluble, whereas only 0 to 15% of the metals were insoluble.

A precise distinction between organic and inorganic color in samples aged 42 hr. is, of course, impossible on the basis of these results because some of the organic materials were probably extracted, and because some of the metals were not extracted. It seems, however, reasonable to conclude that $^6/_{10}$ to $^7/_{10}$ of the total color formed during 42 hr. of aging was *not* associated with inorganic materials.

The Effect of Metals on Depolymerization

In addition to accelerating reversion, metal salts were observed to accelerate depolymerization of cotton linters pulp. The rates with which the pulp underwent depolymerization as measured by intrinsic fluidity (*36*) are shown in Fig. 7.

The rate of chain cleavage was accelerated by the presence of iron and copper sulfates and was slightly retarded by manganous sulfate. Fluidity curves for the control and samples containing manganese and copper salts were linear for the entire aging interval. Fluidities of iron-containing samples increased linearly with time for the first 18 hr. of aging, and appear to have increased linearly for the 18 to 66 hr. interval though at a different rate than for the first 18 hr. The linearity of these rate curves suggests that the apparent kinetics of the chain cleavage reaction are zero order.

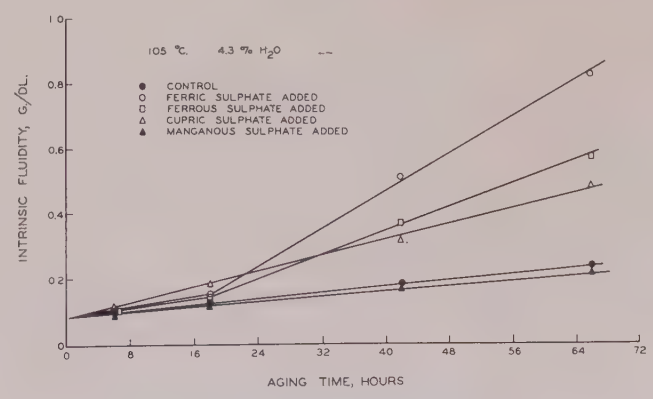


Fig. 7. Intrinsic fluidity versus aging time

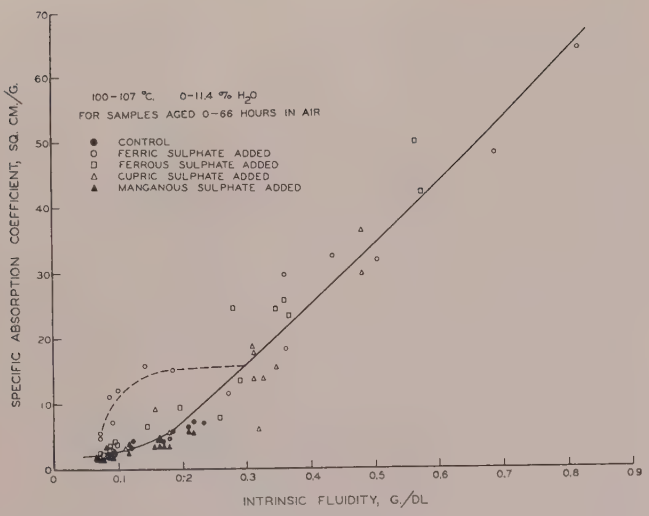


Fig. 8. Specific absorption coefficient versus intrinsic fluidity

Comparison of Figs. 7 and 2 suggests there is a parallelism between the intrinsic fluidity and the specific absorption coefficient of aged cotton linters. Additional fluidity data indicated that metal-induced depolymerization, just as metal-induced reversion, was more extensive at 4% moisture than at 0 or 7%, and was extremely sensitive to aging temperatures above 100°C. These results further suggested that changes in the intrinsic fluidity and specific absorption coefficient paralleled each other. A correlation curve for absorption coefficients and intrinsic fluidities based on data from several independent trials is shown in Fig. 8.

There appears to be a linear relationship between k and the extent of chain scission incurred by the linters during accelerated aging. It is significant that large increases in k appear to have occurred only where extensive chain cleavage has also occurred.

The Influence of Atmospheric Oxygen on Reversion

In order to determine the extent to which atmospheric oxygen participated in metal-induced reversion, samples of cotton linters were conditioned in an atmosphere of nitrogen containing less than 0.1% oxygen and having a relative humidity of approximately 23%. Without removing the samples from the nitrogen atmosphere, they were sealed in aging chambers and aged at 105°C.

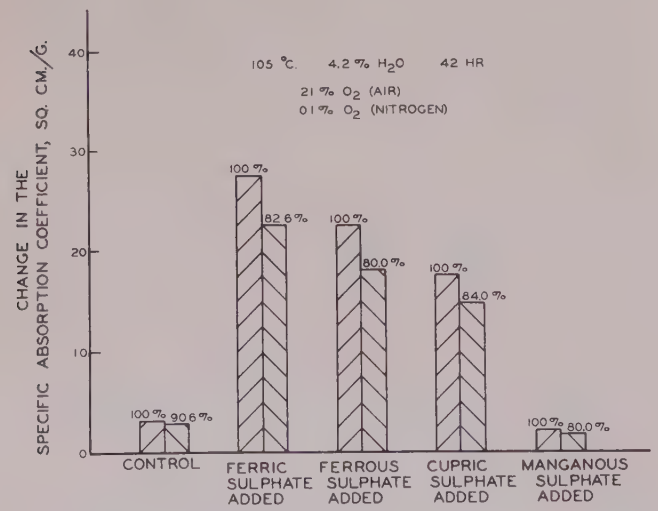

105 °C. 4.2 % H_2O 42 HR
21 % O_2 (AIR)
0.1 % O_2 (NITROGEN)
CHANGE IN THE SPECIFIC ABSORPTION COEFFICIENT, SQ. CM./G.
100 % 90.6 %
100 % 82.6 %
100 % 80.0 %
100 % 84.0 %
100 % 80.0 %
CONTROL
FERRIC SULPHATE ADDED
FERROUS SULPHATE ADDED
CUPRIC SULPHATE ADDED
MANGANOUS SULPHATE ADDED

Fig. 9. Effect of atmospheric oxygen on the change in the specific absorption coefficient

with other samples conditioned in air at 22.9% R.H. Changes in k_{42} for both sets of samples are shown in Fig. 9.

Reduction of the oxygen concentration in the aging atmosphere from 21% to less than 0.1% reduced the extent of reversion only 10% for the control and 16 to 20% for the metal-containing samples. These results, together with consideration of the nature and concentration of the metal salts added to the linters, suggest that reactions other than oxidation were responsible for the major portion of metal-induced brightness reversion.

Ultraviolet and Infrared Spectra of Cotton Linters

If colored organic materials of a particular type were a cause of metal-induced reversion, then it is possible that they, or intermediates involved in their formation, could be identified on the cotton fibers. In an effort to make such an identification, samples of cotton linters were analyzed spectrophotometrically in the ultraviolet and infrared regions of the spectrum.

Ultraviolet reflectance curves were obtained through the courtesy of the Beckman Instrument Co. on the Beckman DK-2 recording spectrophotometer. The reflectances, R_∞, of thick pads were measured in reference to a magnesium carbonate block, and were converted into k/s ratios using the Kubelka-Munk equation, $k/s = (1 - R_\infty)^2/2R_\infty$. For these calculations the reflectance of the magnesium carbonate was taken as 100%.

Values of k/s for unaged samples are shown in Fig. 10 and for aged samples in Fig. 11. Data for wavelengths between 270 and 280 mμ are not included because reflectances below 280 mμ were determined several weeks later than reflectances above 270 μ. The two sets of data did not coincide where they overlapped, making the precise location of the k/s curves uncertain. All reflectances below 280 μ were measured at the same time so that there is no uncertainty as to the occurrence of maxima in k/s versus wavelength plots for aged samples.

Figures 10 and 11 show that a material absorbing selectively at 250–260 μ was formed on cotton linters during aging, and that larger amounts of this material were formed in samples containing iron and copper sulfates than in the control or the sample containing manganous sulfate. Compounds which exhibit this type of absorption spectra (*37*) and which are derivable from cellulose (*37*, *38*) occur among the furan derivatives. Such derivatives should, therefore, be given consideration as possible origins of the absorption

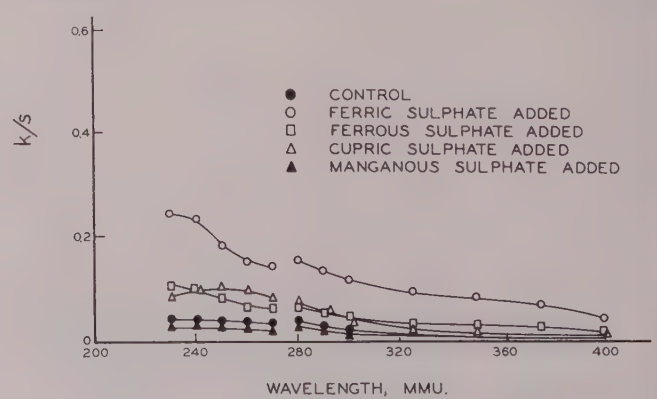


Fig. 10. Initial k/s versus wavelength

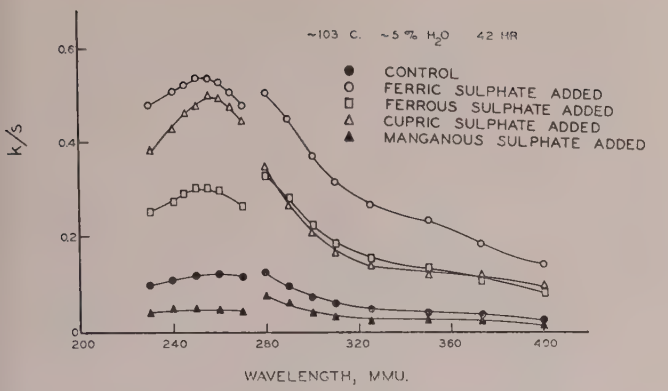


Fig. 11. Terminal k/s versus wavelength

maxima in aged cellulose, and as possible intermediates in the reactions causing the discoloration of aged cotton linters.

The infrared transmission spectra of finely ground cotton linters pressed into potassium bromide pellets were measured on a Perkin-Elmer Model 21 recording spectrophotometer. The unaged control and a sample aged 42 hr. in the presence of copper sulfate were analyzed in this way and no differences were noted in their spectra. Apparently, the materials causing the absorption maxima in the ultraviolet were not present in sufficient amounts to be detected in the infrared.

Hydroxymethylfurfural in Aged Cotton Linters

Because in the absence of pentosans the most likely furan derivative which could be formed from cotton linters pulp is hydroxymethylfurfural (HMF), the following experiments were performed to see if this compound could be identified in aged linters.

Four-gram portions of aged samples were extracted with 90 ml. of water for 4 hr. at room temperature. The extracts were filtered, diluted with washings to 100 ml., neutralized with sodium hydroxide to a pH of 7.0 to 7.5, concentrated under vacuum at 30°C., and spotted together with a known amount of authentic HMF on prewashed (with ethyl alcohol) Whatman no. 1 chromatographic paper. The chromatogram was developed for about 18 hr. with butanol saturated with 2% aq. NH_3, dried, and the known HMF spots located with color reagents or an ultraviolet lamp. Those areas of the paper suspected to contain HMF from the extract were cut out and eluted with ethyl alcohol. The eluates were diluted to 5 ml. and their ultraviolet absorption spectra determined with reference to the alcoholic eluate from an equal area of the chromatogram.

Log absorbance versus wavelength curves for HMF eluted from the chromatogram, and for the eluate from a sample aged in the presence of ferric sulfate are shown in Fig. 12. The curves have been shifted to coincide at 281 μ in order to compensate for the difference in their concentrations. The two curves were quite similar in the wavelength range 240 to 310 μ suggesting that the same material was responsible for the absorption of both solutions.

Assuming that HMF was actually responsible for these absorption maxima, the concentration of HMF in the alcoholic eluates was estimated at 1.2 γ per ml. for the sample aged in the presence of ferric sulfate, and 0.5 γ per ml. for an aged control. No maxima were noted for eluates from unaged samples.

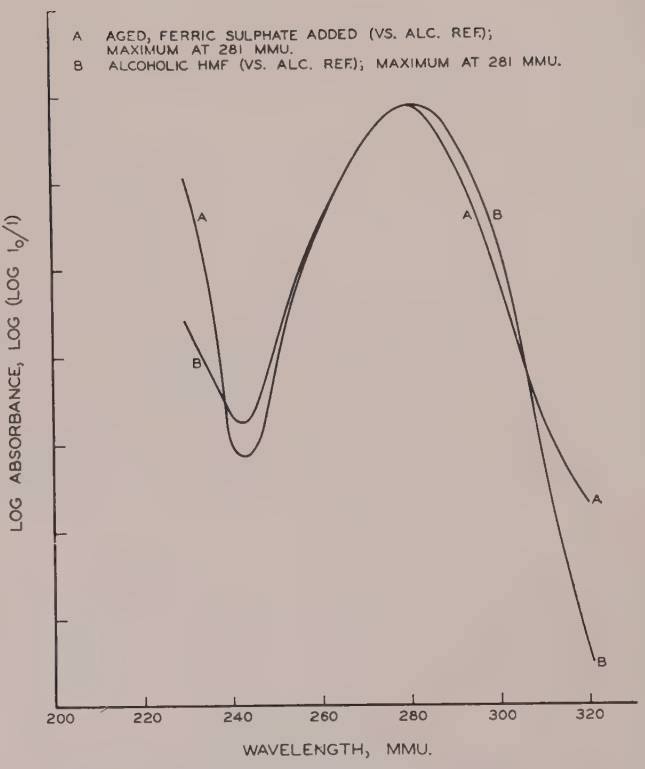


Fig. 12. Ultraviolet absorbance of alcoholic eluates

Kinetic Considerations

One interpretation of the foregoing data is that metal-induced reversion in cotton linters consists partially of hydrolytic degradation of cellulose to low molecular weight products and subsequent dehydration of these products to highly colored materials. If so, then the observed rate of discoloration should be consistent with the rate of product formation calculated for two consecutive reactions which obey the same rate laws as hydrolysis and dehydration of carbohydrates.

Although a divergence of opinion exists about the actual kinetics involved in the heterogeneous hydrolysis of cellulose, zero order kinetics are generally believed to best describe low levels of degradation (*36*).

The kinetics of the dehydration of hexose sugars to HMF have not been described; however, the formation of furfural from xylose is considered to be a first order reaction (*37*). Moreover, resinification of furfural in dilute, aqueous acid is also believed to be a pseudo-unimolecular reaction (*37*). If the reactions of glucose and HMF are assumed to be analogous to those of xylose and furfural, then the occurrence of first order reactions in the second step of the proposed mechanism seems quite possible.

Certainly the reactions proposed to follow hydrolysis must occur in several steps and probably involve several intermediates; but for an over-all reaction consisting of first order reactions, the over-all rate is dependent upon the rate of the slowest reaction in the sequence (*39*). For this analysis it was assumed that a single first order rate equation could describe the over-all rate of the several reactions making up the second step of the proposed mechanism.

For a reaction,

$$A \xrightarrow{r_1} B \xrightarrow{r_2} C$$

in which reactant A forms product B according to zero

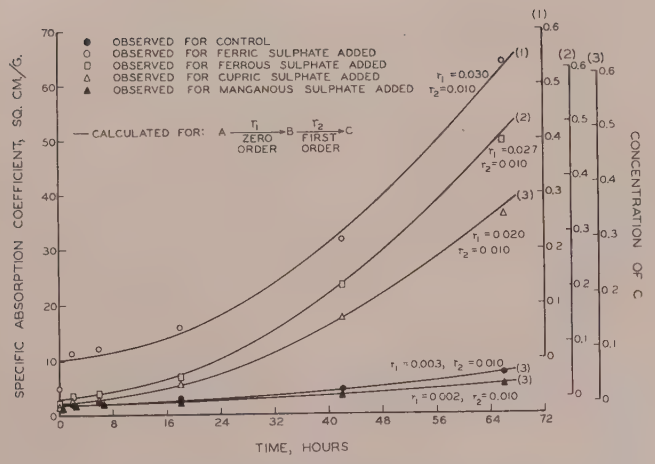

OBSERVED FOR CONTROL
OBSERVED FOR FERRIC SULPHATE ADDED
OBSERVED FOR FERROUS SULPHATE ADDED
OBSERVED FOR CUPRIC SULPHATE ADDED
OBSERVED FOR MANGANOUS SULPHATE ADDED
CALCULATED FOR: A → B → C
ZERO ORDER
FIRST ORDER
SPECIFIC ABSORPTION COEFFICIENT, SQ. CM./G.
CONCENTRATION OF C
TIME, HOURS

Fig. 13. Specific absorption coefficient versus aging time and concentration of C versus time

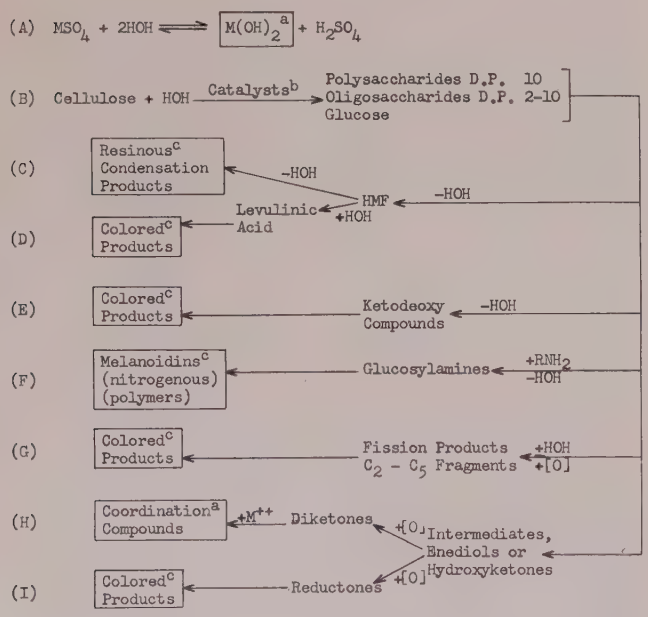
order kinetics with a rate constant of r_1[moles/(liter-hr.)], and B reacts further to form product C according to first order kinetics with a rate constant of r_2[1/hr.], it may be said that

$$dy/dt = r_1 - r_2 y, \text{ and}$$
$$dz/dt = r_2 y$$

In these equations y is the concentration (moles per liter) of B and z the concentration (moles per liter) of C at time t. Integrating and solving these equations for z as a function of time yields the following expression:

$$z = r_1 (t\, e^{-r_2 t}/r_2 - 1/r_2)$$

The variation of z as a function of time for assumed values of r_1 and r_2, together with the observed rates of reversion for cotton linters with and without added metal sulphates are shown in Fig. 13. These results suggest that a hydrolysis-dehydration mechanism of reversion is not inconsistent with kinetic considerations.



[a] Source of inorganic color.

[b] Catalysts may be MSO_4, $M(OH)_2$, or H_2SO_4.

[c] Source of organic color.

Fig. 14. Some possible pathways for heat-accelerated, metal-induced brightness reversion

INTERPRETATION

Although discoloration in materials as chemically and physically complex as papermaking pulps is undoubtedly the result of many different reactions, the accumulated data suggest that, in the case of metal-induced reversion in purified cotton linters, color was formed as the result of the following sequence of reactions:

Sorption of Metal Salts. Cotton linters, suspended in a solution containing 1 p.p.m. of a metal salt, sorb and retain a portion of the salt during handsheet formation. At this low salt concentration, a salt like ferric sulphate will hydrolyze (reaction A in Fig. 14), and it is probable that basic hydroxides as well as unhydrolyzed salt are sorbed. A consequence of this behavior is that handsheets containing ferric sulphate have a larger initial absorption coefficient, k_0, relative to the control, than handsheets containing other metals which have a smaller tendency to hydrolyze *or* which form less intensely colored hydroxides than ferric hydroxide.

Hydrolysis of Sorbed Metal Salts. Raising the temperature of a salt solution, in most cases, causes the hydrolysis constant of the salt to become larger. Therefore, heating handsheets that contain metal salts and moisture might be expected to cause the sorbed salts to hydrolyze further. This type of reaction, resulting in the formation of additional hydroxide, could account for the increment in k formed during the first two hours of aging. This interpretation is supported by the fact that the color formed during this period is readily removed by treatment with dilute acid.

Depolymerization of Linters. A second phase of reversion is initiated when the linters undergo depolymerization, a reaction which is accelerated by the presence of iron and copper sulfates. Depolymerization may be symptomatic of oxidative, pyrolytic, or hydrolytic degradation. In this investigation, aging was conducted below pyrolytic temperatures, and the only oxidant (atmospheric oxygen) present in sufficient quantities to degrade the linters was removed without greatly reducing the extent of reversion. These facts suggest that the attack was largely hydrolytic in nature.

For hydrolysis of cellulose some water must be present during aging. But if too much moisture is present, the small amounts of inorganic catalysts which promote depolymerization will become too dilute for optimum effect. This concept could account for the maximum which the terminal absorption coefficient, k_{42}, exhibits at approximately 4.0% moisture.

Decomposition of Hydrolysis Products. Hydrolysis of cellulose (reaction B in Fig. 14) may proceed locally to such an extent as to produce low molecular weight fragments and eventually glucose. But neither the intermediates nor the glucose are colored substances. Hence, it is postulated that glucose, and perhaps other small fragments, undergo further reactions which eventually produce colored substances.

Several pathways can be visualized by which glucose may react under the conditions of aging to yield colored products. Some examples are shown as reactions C through I in Fig. 14. Although little can be said about

the relative importance of the pathways, the spectrophotometric indication of hydroxymethylfurfural can be used as an argument that reactions C and D in Fig. 14 participate in reversion.

CONCLUSIONS

The data and other information presented in this report warrant the following conclusions:

Traces (approximately one microgram-atom of metal per gram of pulp) of certain added metal salts affect the initial coefficient, k_0, of handsheets prepared from purified cotton linters. Increases in k_0 are due almost entirely to the retention of inorganic compounds and occur only if the salt or its hydrolysis products are colored substances.

During heat-accelerated aging in sealed chambers at temperatures between 100 and 107°C., the order in which sulfate salts affect the terminal absorption coefficient, k_{42}, is

$$\text{Fe} > \text{Fe} \geq \text{Cu} > \text{Al} \geq \text{Control} \geq \text{Cd} \geq \text{La} \geq \text{Mg} \geq \text{Mn}$$

This order, except for the positions of aluminum and magnesium, is consistent with the order of cationic acidity as measured by the pH at which precipitation of the metal hydroxides begins.

Although the more pronounced effect of the salts, as measured by k_{42}, is to accelerate reversion, at least in the case of manganese there is significant inhibition of reversion.

Metal-induced reversion in cotton linters pulp is dependent on the amount of moisture present during accelerated aging. The terminal absorption coefficient, k_{42}, exhibits a maximum, which, for the points actually tested occurs at about 4% moisture. This effect is most pronounced with iron and copper salts.

Metal-induced reversion proceeds in two distinct phases. The first phase is complete after two hours of accelerated aging, and is due largely to the formation of inorganic reaction products. The second phase, on the other hand, shows no signs of reaching completion even after 66 hr. of accelerated aging, and is due largely to the formation of organic reaction products.

In its second phase, metal-induced reversion, as measured by the specific absorption coefficient, k, is in general paralleled by hydrolytic depolymerization as measured by the intrinsic fluidity. Since hydrolysis of cellulose, even to glucose, results only in colorless fragments, the latter must undergo further reactions before the observed increases in k can occur. The possible presence of hydroxymethylfurfural may be a clue to the nature of the reactions leading from glucose, etc., to the organic pigments.

Kinetically, the sequence of reactions comprising this second phase of metal-induced reversion may be described by an equation calculated for two consecutive reactions, of which the first is a zero order reaction, applicable to the hydrolysis of cellulose, and the second a slower first order reaction, applicable to the dehydration and condensation of the hydrolysis products.

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Rheological Properties of Suspensions and Polymeric Solutions

A. B. METZNER

This paper is divided into two sections. The first, a short descriptive portion, considers the properties of all known real fluids briefly and the relative position of coating stocks within this general spectrum of fluid behavior. The second and major portion of the paper discusses in detail the types of behavior exhibited by materials such as coating stocks. The measurement, interpretation, and use in design of these physical properties are discussed. Experimental data on both suspensions and polymeric materials are presented.

NOMENCLATURE

(Note: Units given are the usual engineering ones but any other consistent set may be used.)

D, D_i, D_o	= diameter, ft. (D_i and D_o refer to bob and cup diameters of rotational viscometers)
du/dr	= shear rate, sec.$^{-1}$
d	= differential operator, dimensionless
g_c	= dimensionless conversion factor, 32.2 (ft.)(lb.$_M$)/(sec.^{2})(lb.$_F$)
K	= fluid consistency index (lb.$_F$)(sec.)^n/(ft.^{2}), as defined by the equation $\tau = K\,(du/dr)^n$
K'	= fluid consistency index (lb.$_F$)(sec.)$^{n'}$/(ft.^{2}), as defined by the equation for laminar flow in a round tube: $\tau_w = D\Delta P/4L = K'(8V/D)^{n'}$
k_1, k_2	= instrument constants (see ref. (15), for example)
L, l	= length, ft.
N	= rotational speed, r.p.m. or r.p.s.
n, n'	= flow behavior indexes which characterize the degree or extent of non-Newtonian behavior of category I fluids, dimensionless. They are defined by the same equations used to define K and K', respectively. For the special case of Newtonian behavior, $n = n' = 1.00$
n''	= $d(\ln t)/d(\ln N)$, dimensionless
ΔP	= pressure drop through a tube of length L, lb.$_F$/ft.^{2}
R	= cone diameter, ft.
r	= linear or radial distance, ft.
s	= D_o/D_i, dimensionless
t	= torque, ft.-lb.$_F$
V	= average or bulk velocity of fluid flowing through a tube, ft./sec.
α	= angle between cone and plate, radians
γ	= strain or fractional deformation $\Delta L/L$ of a body, dimensionless
Δ	= denotes a difference or change in the following physical quantity, dimensionless. For example, ΔP denotes a pressure difference or pressure drop
θ	= time of shear, sec. or hr.
μ	= Viscosity of a Newtonian fluid, lb.$_M$/(sec.)(ft.). For other fluids, simply the ratio of shearing stress to shear rate at any chosen value of the stress
τ	= shear stress, lb.$_F$/ft.^{2}
τ_w	= point value of τ evaluated at the wall of a round tube
ϕ, ϕ_1, ϕ_2	= unspecified functional relationships

PERSPECTIVE: IMPORTANCE AND COMPARATIVE POSITION OF VARIOUS TYPES OF FLUID BEHAVIOR

THE fluids in Table I have been grouped according to their flow characteristics, a subdivision which emphasizes the differences between the physical properties of various real materials and therefore the differences between theoretical analyses directed toward solution of problems in fluid mechanics, such as those encountered in paper coating. The equation describing a Newtonian fluid

$$\tau = \mu/g_c(du/dr) \qquad (1)$$

contains only one fluid physical property, the fluid viscosity μ. Knowledge of the variation of viscosity with temperature (and, in a few cases, with pressure) therefore serves to define the laminar flow behavior of the fluid completely.* Since the other fluid systems of Table I are more complex, more than one physical property is needed to describe their flow behavior completely.

Table I. Types of Fluid Behavior

Category I

Fluids for which shear rate depends only on the imposed shearing stress:

(a) Newtonian: $du/dr = \left(\frac{g_c}{\mu}\right)\tau$

or

$$\tau = \mu/g_c\,(du/dr) \qquad (1)$$

(b) Non-Newtonian: One example is that of fluids which obey the so-called "Power-law":

$$\tau = K\,(du/dr)^n \qquad (2)$$

Category II

Non-Newtonian for which shear rate depends on imposed stress, and in addition, upon the duration of the stress:

$$du/dr = \varphi_1\,(\tau, \theta)$$

Category III

Non-Newtonian fluids for which shear rate depends on the imposed stress and the extent of deformation (strain):

$$du/dr = \varphi_2\,(\tau, \gamma)$$

Category IV

Fluids for which shear rate depends on shear stress and intensity of an imposed magnetic field.

Category V

Fluids which must be considered as being made up of discrete particles rather than as continuous media.

The simplest type of non-Newtonian behavior (category Ib), in which complications due to time of shear and strain are absent, appears to be common to most slurries or suspensions of solids in liquids. In addition, a number of polymeric materials and their solutions approximate this behavior. Fluids which have been described variously as plastics, Bingham plastics, pseudoplastics, dilatant materials (*23*) and as "generalized Newtonians and non-Newtonians" (*14*, *38*) all fall into this category.

A. B. METZNER, University of Delaware, Newark, Del.

* Under turbulent conditions the fluid density is also of importance but the viscosity is the only molecular *flow* property of significance even in this case.

The second category of fluid behavior tabulated in Table I requires the modification of shear stress-shear rate relationships, such as equation (2), to include the additional variable of time of shear. This category includes the so-called thixotropic and rheopectic fluids (*23*). While thixotropic behavior is of considerable commercial importance (especially in the paint industry) from the viewpoint of imparting desirable physical properties to a product, no engineering studies of long-range merit appear to be available on either thixotropic or rheopectic systems. A primary reason for this delay lies in the relative unimportance of such studies from an industrial processing viewpoint: equipment usually must be designed to accommodate the extremes of the fluid physical properties, which are in this case encountered at either zero or infinite† times of shear. Under both of these limiting conditions, thixotropic and rheopectic materials degenerate into fluids of category I and equipment design offers no additional difficulties over those encountered with the non-Newtonian fluids of category I. Complications due to the properties of category II are of importance in a number of other instances, however. For example, in the inlet region to a tube (which, in the case of a short-tube heat exchanger may include the entire tube!) the rates of disappearance of the abnormal pressure gradients and velocity profiles may be appreciably different for fluids of category I than for those of category II. Problems such as this—involving peculiarities in equipment geometry rather than constant flow conditions—have only been sparsely studied for fluids of category I (*2, 6, 10, 13, 21, 46*) hence the time for studying such complications with category II fluids is hardly at hand as yet. As engineering design procedures for non-Newtonian systems become more erudite, studies of fluids of category II will take on more importance as many of the real materials presently grouped into category I possess thixotropy to a mild degree. This statement seems to emphasize a point of view expressed by Reiner (*37*): as new studies extend into hitherto unreached experimental conditions it may be expected that many fluids which now are believed to be very simple in behavior may prove to be much more complex.

Of much greater immediate importance are fluids of category III, commonly termed "viscoelastic." Most polymers and their solutions possess some viscoelasticity, many of them to a very marked degree. While the pioneering studies of Weissenberg in particular (*45*) in this area are quite well known, only recently have extensive rheological studies of viscoelasticity become available (*3, 12, 16, 17, 29, 31, 32, 34, 37, 40*).

Fluids of categories IV and V will not be discussed in the present paper—they are included in Table I primarily to present the correct over-all perspective. However, the qualitative similarities between problems in magnetohydrodynamics and in non-Newtonian fluid mechanics are astounding: the flattening of the laminary velocity profiles of electrically conducting fluids exposed to transverse magnetic fields is directly analogous to the flattening obtained as one increases the degree of non-Newtonian behavior (i.e., as one decreases, n, the flow behavior index, of equation (2)).

† "Infinite" times of shear are meant to designate times sufficiently long to produce shear stress-shear rate relationships which do not vary with any further increases in time of shear.

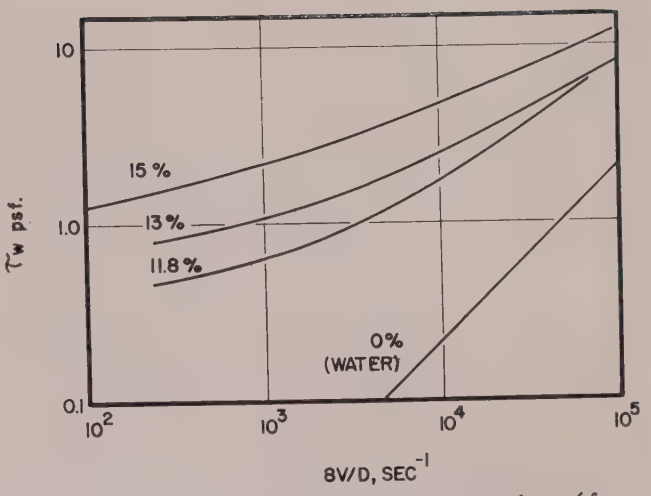

Fig. 1. Flow curves of Attasol clay suspensions (from ref. (9))

Similarly, the delays in onset of turbulence obtained in magnetohydrodynamics (*7*) have a direct counterpart in non-Newtonian systems (*10*).

In summary, the important properties of most paper-coating materials may be expected to fall into categories I and III of Table I: in suspensions (as of clays, starches, and pigments), latices, and some emulsions viscoelastic effects are usually absent and complications due to category II behavior may frequently be neglected. Therefore, category I behavior is indicated. On the other hand, in most polymer solutions (including CMC slips and glues) and polymeric melts viscoelasticity is a primary characteristic and complications due to category III behavior must be considered.

MEASUREMENT AND INTERPRETATION OF FLUID PROPERTIES

Category I Behavior

Measurement of Fluid Properties. Typical flow curves for category I fluids are shown in Fig. 1 and 2. These relationships may be obtained using several distinct types of viscometric equipment (*21*). Only the two most usual units will be described here.

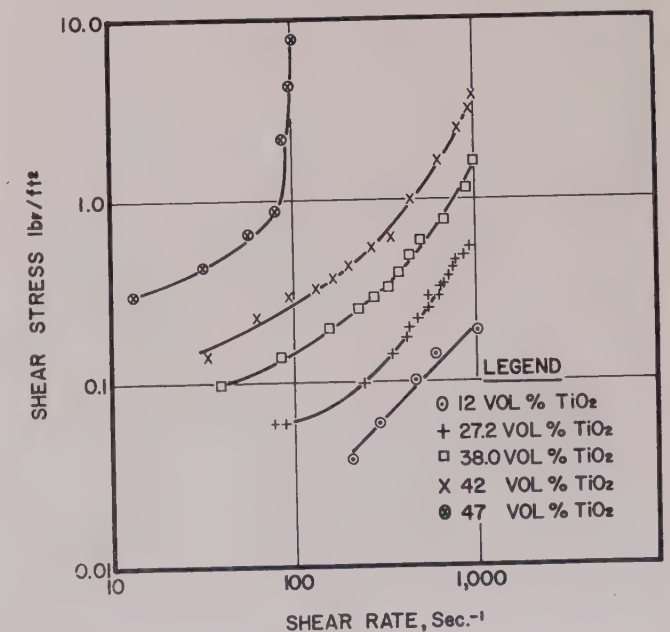

Fig. 2. Flow curves of TiO_2 suspensions (from ref. (24))

(a) Capillary tube viscometers, such as the Severs rheometer (*4*), represent perhaps the most versatile viscometric equipment available. In these instruments, one simply measures the pressure drop and flow-rate relationships of the fluid passing through a round tube under laminary flow conditions. The shear stress at the tube wall, τ_w, may, by means of a force balance on the tube, shown to be equal to

$$\tau_w = \frac{D\Delta P}{4L} \tag{3}$$

Similarly, the shear rate at the tube wall has been shown (*23, 25, 36*) to be equal to

$$(du/dr)_w = \frac{3n' + 1}{4n'} \frac{8V}{D} \tag{4}$$

for *all* category I fluids. The only experimental complication lies with the determination of the pressure drop, ΔP, over tube length L. Normally one measures the pressure loss over a tube of length L *and* an inlet region to the tube. Such a gross pressure loss must be corrected for the pressure loss required in overcoming entrance effects, incuding the kinetic energy imparted to the fluid. For fluids having flow-behavior indexes (n or n') of unity or less, these entrance effects can usually be taken equal to $1.14\rho V^2/g_c$ (*9*). However, for very concentrated suspensions which frequently exhibit dilatancy, the actual entrance pressure losses are sometimes much larger than this figure, presumably due to partial blockages at the entrance to the tube. For example, Riggs (*39*) found entrance losses for concentrated starch pastes equivalent to straight tube lengths of as much as 460 diameters. In such instances the corrected ΔP required in equation (3) can be obtained only by use of very great tube lengths (such that an entrance L/D of even 460 is negligible) or by making measurements in a series of tubes, with various L/D ratios, and determining the entrance pressure loss by cross-plotting the total ΔP versus L/D, for constant values of $8V/D$ (*1, 5, 39*).

The development leading to equation (4) presupposed the absence of "slippage" effects at the tube wall. Such fluid slippage has been observed to occur when the continuous phase separates from the particles of the suspension to provide a thin film of low viscosity immediately adjacent to the tube wall. Most of the shear then occurs in this low-viscosity region and the remainder of the suspension moves as a nearly solid plug through the core of the tube. Such slippage is especially prevalent when the particles of the suspension are relatively large in size in comparison to the tube diameter, as in the flow of paper pulp suspensions (*8*). Rigorous corrections for slippage effects in tubes are available (*25, 27*), but will not be discussed in detail since the problem is not frequently encountered with fluids of interest here.

In conclusion, it is seen that rigorous corrections are available which permit calculation of the true shear stress-shear rate relationships from tube-flow measurements. In view of the rigorous nature of the methods used to interpret data, and of the wide ranges of shear stress and shear rate which may be covered by simply varying the length and diameter of the tubes used (of equations (3) and (4)), it is evident that capillary tube viscometers represent an extremely powerful measurement technique. Thus, thousand-fold ranges of shear rate are readily covered and ranges of 10^6 are quite possible, if required. The chief disadvantage of these viscometers is that the measurements are quite time-consuming—as much as a day may be required to obtain a single flow curve if all the corrections discussed above are necessary.

(b) Rotational viscometers, such as the commercial Brookfield or the Ferranti-Shirley rotational and cone-and-plate viscometers may also be used to provide the data necessary to calculate true flow curves. In this case, the torque versus rotational speed measurements are reduced to the flow curve parameters by the relationships (*15, 23*) for bob-and-cup (concentric cylinders) instruments:

$$\tau_i = \frac{2t}{\pi D_i^2 l} \tag{5}$$

and

$$\left(-\frac{du}{dr}\right)_i = \frac{4\pi N}{1 - 1/s^2} \left\{1 + k_1\left(\frac{1}{n''} - 1\right) + k_2\left[\left(\frac{1}{n''} - 1\right)^2 + \frac{d\left(\frac{1}{n''} - 1\right)}{d(\log t)}\right]\right\} \tag{6}$$

or

$$\left(-\frac{du}{dr}\right)_i = \frac{4\pi N}{n''} \tag{7}$$

Equation (6) gives the correct shear rate only if s is equal to 1.2 or less, otherwise more terms in the infinite series solution must be retained. For the other limiting case ($s \rightarrow \infty$), the solution reduces to equation (7).

The corresponding equations for cone-and-plate instruments are (*19, 21, 35*):

$$\tau = \frac{3t}{2\pi R^3} \tag{8}$$

and

$$du/dr = \frac{2\pi N}{\alpha} \tag{9}$$

The end-effect problem is absent in cone-and-plate viscometers, hence no corrections are required. While the same may be true of well-designed concentric cylinder viscometers (*20, 26*) most units which are commercially available do not have this feature. The usual procedure is to determine a "corrected" length of the bob in equation (5) using a Newtonian fluid of known viscosity, and to assume that this correct length will be the same in non-Newtonian fluid systems. While no theoretical basis may be claimed for this procedure, acceptable results are obtained (*28*).

The problem of slip in concentric cylinder viscometers has been treated by Mooney (*25*) and Oldroyd (*27*). In cone-and-plate viscometers the presence of slip would probably cause the fluid sample being sheared to be thrown out of the instrument, hence experimental data can probably not be obtained in this type of instrument when appreciable slip is present—at least not without introducing end effects through the addition of retaining rings. Additionally, interpretation of the data could not be made since the shear rate would now become an unknown function of radial position within the fluid sample (*27*).

The primary advantage or rotational viscometers over capillary tubes lies in the ease and rapidity with which

data may be obtained: an entire flow curve may be traced out in as little as a few minutes. The disadvantages are largely due to the particular designs used in commercial units, rather than due to the inherent limitations of the general type of equipment. Thus, for example, the power available in most instruments is insufficient to enable measurements at very high shear rates in highly viscous systems. Further, the maximum shear rates obtainable in any unit presently available commercially are about 20,000 sec.$^{-1}$. Several units are operative only in uninterestingly low regions of shear rate or over very limited ranges. Slurries and dilute solutions tend to be thrown out of the gap formed between a cone-and-plate, by centrifugal force, at fairly low shear rates. The problem of heat generation due to viscous shear is inherently more serious in rotational viscometers than in capillary tubes since the bulk flow in the latter units serves to carry out much of the heat as it is generated. While proper design may minimize the problem in rotational instruments, such design features have not frequently been carefully considered. Most important of all, a large variety of commercial rotational units are available in which the idealized geometry assumed in developing equations (5) to (9) is not employed—hence satisfactory interpretation of the results is theoretically as well as practically impossible.

In conclusion it is seen that a well-designed rotational viscometer has important advantages over capillary tubes in the ease with which data may be obtained. However, the ranges over which useful data may be obtained, with available instruments, is more limited. Further, poor design prohibits the use of many instruments for any scientific purpose whatever.

Interpretation of Fluid Properties. In Fig. 1 the shear stress is plotted versus $8V/D$, as directly obtained from experimental data. This term can be readily converted into shear rate by means of equation (4), since n' is equal to the slope of the curves of Fig. 1 at any chosen value of $8V/D$. Prior studies (*28*) have shown that data such as these agree extremely well with measurements from a rotational viscometer, as of course, they should.

The data for clay slurries shown in Fig. 1 exhibit the gentle curvature common at high shear rates: as the non-Newtonian (low slope) portion of the flow curve approaches that of the suspending medium (water), which, of course, it cannot cross, the flow curve bends upward. That is to say, at sufficiently high shear rates slurries again approach Newtonian behavior, with a viscosity only slightly greater than that of the suspending medium.

The "power law" equations frequently used to correlate rheological data, viz.

$$\tau = K'(8V/D)^{n'} \qquad (10)$$

or

$$\tau = K(du/dr)^{n} \qquad (11)$$

may be applied rigorously to any straight-line portion of these curves. The controlling question which always arises is whether or not these straight-line regions are sufficiently broad to enable use of either equation (10) or (11) over appreciable ranges of $8V/D$ or shear rate. Inspection of the curves reveals that power law behavior is obeyed over at least one decade of shear rates. This is sufficient for almost all practical problems *provided* one estimates correctly the approximate range in which one is operating. For example, in a knife coater the shear rate is simply given by the linear velocity of the paper or fabric surface divided by the clearance. Roll coaters (calenders) have been treated by Marshall (*18*).

Figure 2 shows data on another pigment which is perhaps of greater interest to the paper industry. In this case, the shear stress-shear rate curves are also concave upwards but, instead of approaching a slope of unity at the highest shear rates, the slope increases more or less indefinitely. Such *dilatant* behavior (for which n and n' are greater than unity) is commonly observed in many concentrated suspensions (*24*) (the 47% volume per cent slurry corresponds to 79% by weight). Similar data, for vinyl resin plastisols, are also given by Severs (*41*) and Otto (*28*).

Two extremely important characteristics of these suspensions must be noted:

1. Beyond the shear rate (coating speed) at which dilatancy first occurs the shear stress may increase exponentially with further increases in shear rate. In the case of the 47 volume per cent curve of Fig. 2 this means that coating speeds leading to shear rates above 100 sec.$^{-1}$ are virtually impossible to use: stresses which could rupture the stock being coated may readily be developed at higher shear rates.

2. At shear stresses only a few fold higher than those at which dilatancy of the flow curve first appears but which have not yet been characterized more precisely except for two systems (*24*, *41*) the fluid "ruptures." In other words, a rough, irregular surface—with coating torn away from the surface completely in extreme cases—may be produced.

For both of these reasons careful rheological data are required for new systems which may exhibit dilatancy under coating conditions. It is also seen that extrapolation of the flow properties, using equations (10) or (11), may be greatly misleading in these systems. However, careful determination of rheological properties and calculation of the shear rates to be encountered in the plant can predict accurately beforehand the difficulties which may be encountered and how to correct for them.

Before concluding this discussion of category I behavior the use of single-point viscosity determinations may be briefly considered. The 27.2% solids curve on Fig. 2 exhibits approximately the same shear stress at a shear rate of 1000 sec.$^{-1}$ as does the 11.8% solids curve of Fig. 1. Thus, the conclusion which would be reached from a single measurement of viscosity (shear stress ÷ shear rate) at this shear rate is that both fluids are identical in flow behavior. Comparison of the full curves shows how ridiculously incorrect such a conclusion would be. The clay suspension of Fig. 1 could be coated at many times this speed with only modest increases in the stress exerted on the paper or fabric being coated. By comparison, the fluid of Fig. 2 has already begun to show signs of fracturing at 1000 sec.$^{-1}$. This would undoubtedly prevent any significant increases in coating speed, and may even require decreases, if an acceptable product is to result. Nevertheless, even manufacturers of coating stocks frequently

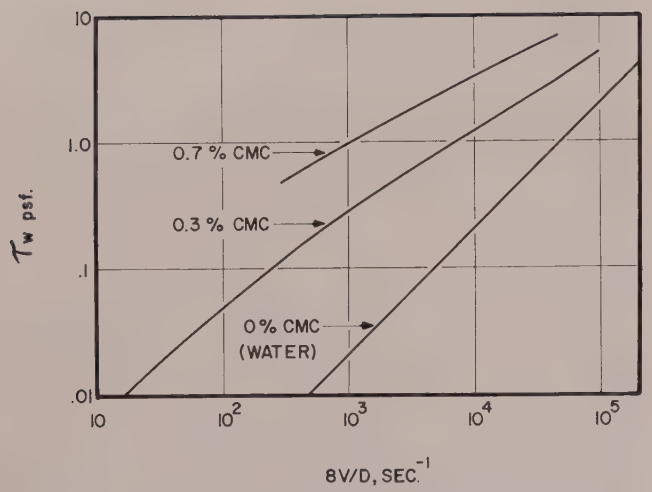

Fig. 3. Flow curves of carboxymethylcellulose dispersions (from ref. (9))

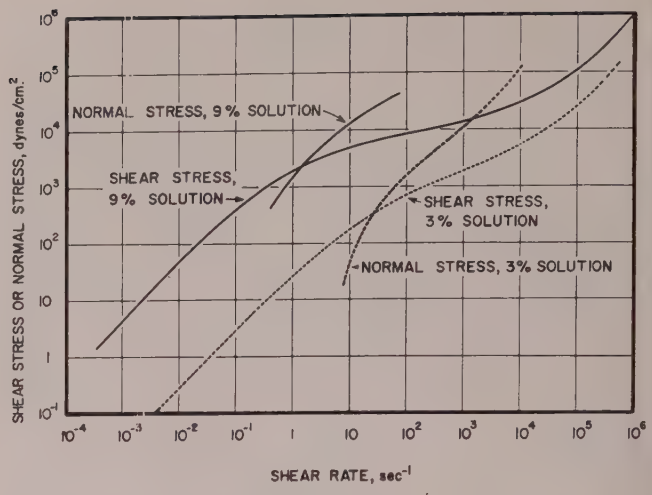
SHEAR STRESS OR NORMAL STRESS, dynes/cm^2
NORMAL STRESS, 9 % SOLUTION
SHEAR STRESS, 9% SOLUTION
SHEAR STRESS, 3% SOLUTION
NORMAL STRESS, 3% SOLUTION
SHEAR RATE, sec^{-1}

Fig. 5. Comparison of the shearing and normal stresses in polyisobutylene solutions (abridged from reference (3))

still list "one point" determinations of the flow properties, presumably under the erroneous impression that such data may be useful.

Category III Behavior

In this case, two sets of material properties must be determined as both influence the use of fluids which fall into this category. These properties are: (a) the shear stress-shear rate behavior; (b) the fluid elasticity.

The shear stress-shear rate behavior of viscoelastic systems undergoing steady shear poses no unusual problems in either measurement or interpretation. Typical results are shown in Figs. 3 and 4. Both sets of data are generally similar to the data of Fig. 1 for clay suspensions and the simple power laws (equations (10) and (11)) are obeyed over fairly broad ranges of shear rate.

However, Figs. 3 and 4 represent an incomplete description of the properties of viscoelastic systems. In particular, fluid elasticity is responsible for the "stringiness" of polymer solutions and glues, for the well-known "Weissenberg" effect observed during mixing, for example, and for elastic recovery or "memory." Thus, the fluid emerging from a coater or issuing from a tube shows an expansion across the direction of shear, and a corresponding longitudinal contraction. Obviously, product quality may be pronouncedly influenced if this stress relaxation is not permitted. Furthermore, "rupture" (*5, 22, 42, 43, 44*) of the fluid may occur if it is stressed too greatly or too suddenly.

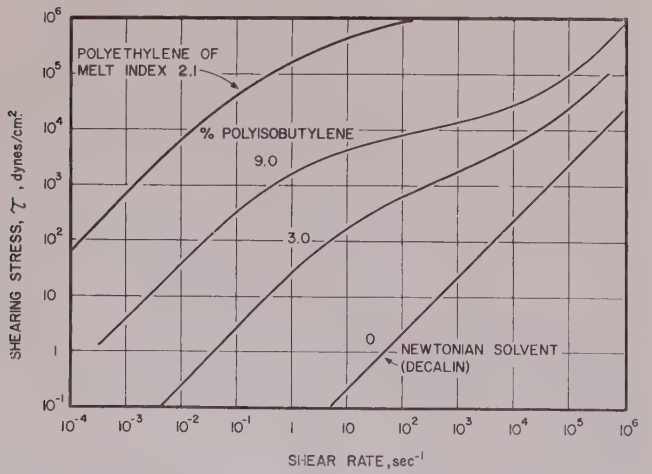

Fig. 4. Flow curves of a polymer melt and of polymer solutions. Upper curve: polymer melt at 125° C. Lower curves: polymer solutions (0, 3, and 9% polymer) at 25° C. Data of Brodnyan, Gaskins, and Philippoff (3) and of Philippoff and Gaskins (33)

Fluid elasticity may be measured by means of the normal stresses which it induces. The data of Philippoff and co-workers (*3*), given in Fig. 5, show that in highly elastic solutions these normal stresses may even exceed the shearing stresses in absolute magnitude.

Measurement of an "elastic modulus" to characterize fluid elasticity has been reported by use of normal stress measurements in cone-and-plate viscometers (*3, 17*) and by means of flow birefringence (*3*). Both experimental techniques are, while well developed, quite difficult to carry out. More recently, Gaskins and Philippoff (*11*) have suggested measurement of the "entrance effect" or pressure loss at the beginning of a tube as a means of characterizing fluid elasticity, as well as the jet trajectory or "bulge" of the fluid emerging from a tube. The former depends on the fact that the fluid must undergo elastic distortion as it flows into a tube, hence the excess pressure loss in an entrance region reflects the fluid elasticity as well as its viscosity. Similarly, the bulging of a jet issuing from a tube is a measure of the fluid elasticity. The appropriate momentum balance derivations relating fluid elasticity to such experimental measurements have been carried out (*30*) but no published experimental verification appears to exist at the time of this writing.

SUMMARY

This paper describes in detail the measurement and interpretation of non-Newtonian fluid properties. The relationships between these properties and coating conditions are briefly discussed. It is seen that category I behavior may be readily measured and the results of these measurements closely related to paper coating conditions. While category III behavior (viscoelasticity) is similarly closely related to choice of proper coating conditions for these fluids, the relationships are only known qualitatively at the present time. Much further work remains to be done in this latter area.

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W. Philippoff and F. H. Gaskins made available their paper on the use of jet trajectories to measure fluid elasticity at an early date and have contributed additionally during many informal discussions of these problems. Much of the author's background in this area was developed during research studies sponsored by the Office of Ordnance Research, U. S. Army.

An Operations Research Approach to the Economic Optimization of a Kraft Pulping Process

CHARLES W. CARROLL

One name given to a systematic approach to broad industrial problems is "Operations Research." Operations Research usually involves setting up a mathematical model which simulates the operating interrelationships of a given process or system. By appropriate manipulation of the variables in the model (counterparts of the system's controllable operating variables), the conditions for maximizing the profitability of the system can be determined. This article is based on a thesis (*1*) which describes an Operations Research approach to the maximization of net dollar return from the operation of a hypothetical but realistic kraft pulping process. The system includes the interrelated digester and recovery cycle operations and the associated revenues and costs involved in the manufacture of an unbleached grade of spruce kraft pulp. In order to represent the entire process by a mathematical model, it was necessary to develop and experimentally verify a suitable rate expression interrelating all the important kraft cooking variables. This expression, and extensive material, energy, and economic balances taken throughout the system, allowed the net dollar return (revenues minus costs) to be expressed as a function of the system's controllable operating variables. This expression for net return, and similar mathematical expressions representing certain realistic restrictions which cannot be violated, comprise the mathematical model of the system. The object of the economic balance is to determine the values of the controllable operating variables which maximize the net return, subject to nonviolation of the restraints considered. The mathematical model, besides having restraints, is nonlinear. This is representative of a very general and industrially important situation. A new approach to the solution (optimization) of this type of model was devised. A computer program was developed and successfully utilized for the desired optimization.

EXPECTATION of profit is the economic driving force motivating business activity in a free-enterprise economy. An increase in this profit for a given organ-

CHARLES W. CARROLL, Graduate Student, The Institute of Paper Chemistry, Appleton, Wis.; present address, Scott Paper Co., Chester, Pa. Work performed at The Institute of Paper Chemistry.

ization can be accomplished by discovering and following any of a number of courses of improved action. Operations Research* provides a scientific approach to the selection of those courses of action best fulfilling a particular objective set forth by management. Often this objective involves more efficient production, and, consequently, much effort has been spent on ways to decrease production costs by seeking "best" or "optimum" operating conditions.

The techniques now used for handling some of the more complicated Operations Research problems have been only recently applied in industry. The history of the development and use of some of these techniques can be found in references (*3*) and (*4*). Briefly, during World War II, large numbers of scientists and engineers from industry were hired by the Allied governments to help solve certain complex military problems. Upon conclusion of the war, these individuals returned to industry and carried with them their wartime experience. They found industrial problems to be well suited to the approach developed during the war. In this way, what had become known as "Operations Research" (O.R.) in military parlance was translated to peacetime industrial activities. Further developments in the business environment were especially rapid.

Today, most O.R. problems involve the mathematical description of complex industrial situations such that, by appropriate solution of the mathematical model, management can be given quantitative information helpful in making better operating decisions. In this way, O.R. helps executives to fully concentrate their abilities on inherently intuitive problem areas demanding, primarily, so-called "business know-how."

The spirit of O.R. is not new. It is, for instance, very familiar to the industrial and chemical engineer through classical problems such as the Economic Lot Size. What is new in O.R. is the development of a systematic and confident *approach* to complex industrial problems, often using characteristic mathematical techniques and employing electronic computers for solution.

THE OPERATIONS RESEARCH APPROACH

The steps of the O.R. approach to an industrial problem may be considered as follows (*2*, *3*):

1. Define the problem. Why is there dissatisfaction with the present operations and what alternative courses of action appear to hold most promise of being effective solutions to the problem, relative to a set of pertinent objectives?

2. Determine a suitable "measure of effectiveness" (often called the "objective") to be optimized. This nearly always involves the dollar-sign. Usually, overall company profits or net dollar return from some suboperation is to be maximized, or certain costs minimized. Thus, most O.R. optimizations are *economic optimizations.*

3. Elaborate a model to represent the system whose optimization is desired. A model may be defined as a device, physical or symbolic, "which behaves in a manner similar enough to some other system so that useful knowledge about the system may be gained from a study of the model"(*7*). Models are almost always necessary in industrial work since experimentation with full-sized industrial equipment disrupts production and is very costly in money and time. [However, see the discussion of "Evolutionary Operation" in, e.g. (*8*, *9*).] And sometimes industrial equipment is only contemplated in design or as replacements.

Usually, the most desirable model is the mathematical model, which employs mathematical statements to represent the system and enables responses to be calculated rather than measured. The measure of effectiveness is expressed as a function of a set of variables at least one of which is subject to control. (The variables involved are often functionally interrelated so that they behave similarly to the active variables in the realistic system simulated.) As the variables are manipulated, their *effectiveness* in optimizing the objective is changed. Thus, the expression giving the effectiveness (E) of a set of levels for the independent, controllable variables $Y1$, $Y2$, . . . may be written

$$E = E(Y1, Y2, \ldots)$$

Often there are restrictions imposed on the values of the independent variables, or functional restraints involving these variables, and such restraints are expressed by supplementary equations and/or in equations.

However, it may happen that operating, theoretical, or empirical information is not available for setting up the entire mathematical model. In this case, an experimental program using laboratory equipment to simulate the appropriate industrial processes and to allow for the determination of the desirable, supplementary operating information is often necessary.

4. Solve the problem: determine the values of the independent (controllable) variables which optimize the objective (i.e., maximize the effectiveness of the system) subject to any restraints imposed on the system (equipment limitations, rigid management policy, operating limitations, minimum quality characteristics, market restrictions, legal limitations, etc.). Standard O.R. techniques are available for solving certain types of recurring problems, and it is desirable if the problem can be so typed [see references (*2*) and (*4*)]. Often, however, a combination of these techniques must be employed or other techniques devised.

The remaining steps in the O.R. approach can be accomplished only on the industrial scene. They are:

5. Test the model and calculated solution obtained from it. If adjustment is indicated, readjust the model, determine a new solution, and check again. A carefully chosen initial model may eliminate difficulties here.

6. Establish controls. The lack of effective control over certain variables might seriously invalidate the appropriateness of the original model. The need for a change in the original controllable variables to offset changes in uncontrollable variables must be recognized and a new optimum solution found. Automatic control systems actuated by electronic "optimizers" are destined to play an even more important part in future industrial operations [see (*1*)].

7. Implement the suggested solution through appropriate organizational channels, and establish a set of

* A general introduction to Operations Research can be found in (*2*, *3*, *4*). Operations Research in the pulp and paper industry is discussed in (*5*, *6*).

operating procedures so that those concerned with control of the operation can attain the optimum as easily as possible.

In carrying out the O.R. approach in industry, it has become customary to employ the "team approach," because the experiences and ideas of such a group having diversified professional backgrounds generally make it easier to set up and solve problems.

Finally, O.R. is importantly characterized by the "systems concept": that is, an attempt to study *all* the interdependent activities and variables related to the problem at hand, all the way through and even outside of the organization. In actual fact, though, virtually every "optimization" in O.R. is really a suboptimization—that is, an optimization of some part less than the whole [see reference (*4*)]. Usually the suboptimum answer is different from that determined in the ideal, over-all optimum because all the factors have not been considered. Often, though, a system is naturally divided into parts which are independent or almost so, or the system is so complicated that even a suboptimization is an achievement.

OPTIMIZATION IN THE PULP AND PAPER INDUSTRY

There are relatively few optimization studies of any kind reported in the technical literature. Several companies in the pulp and paper industry have active O.R. groups which have solved a number of important problems. The details of these studies are not generally available. However, two examples of the application of "linear programming" to special situations in the pulp and paper industry have been published (*10*, *11*).

One area in the pulp and paper industry in which Operations Research can be of considerable importance is pulping. The classical pulping studies are, in general, aimed at discovering the interrelationships among cooking variables, pulp yields, and quality characteristics, dissociated from the "systems concept" and quantitative economic considerations. Thus, the "optimum"conditions one finds discussed in the pulping literature are clearly not (nor do the authors imply them to be) the result of *economic optimizations*.

OPTIMIZATION OF THE KRAFT PULPING PROCESS

The kraft pulping and recovery cycle operations comprise a reasonably isolated, yet complex, subsystem of an integrated papermaking process. Figure 1 indicates this relationship. This paper considers an Operations Research approach to the economic optimization of a hypothetical, but realistic, kraft pulping process.*

The Hypothetical Kraft Pulping System

The hypothetical system considered is shown in simplified form in Fig. 2. It consists of the interrelated digester and recovery cycle operations for a kraft mill producing, under certain realistic conditions, a fixed daily amount of unbleached spruce pulp. Involved also are certain typical revenues and variable costs, and a number of realistic restraints. [The details of this system are developed in (*1*).]

* The completed *study* itself (as opposed to the O.R. *approach* presented above) is, perhaps, more closely allied to so-called Systems Engineering than Operations Research. This is because the system involved deals predominantly with technical operations rather than the more intangible business considerations often characterizing Operations Research. See reference (*12*).

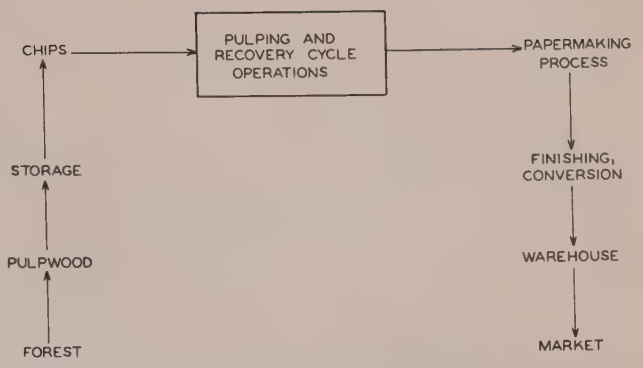

Fig. 1. An integrated papermaking process

It should be noted in Fig. 2 that a *design* cost (capital recovery plus interest for the evaporators) is included and is considered as a variable cost. Similarly, the restraint, *R*7, setting a limit to the amount of capital available for purchasing evaporators, is a realistic restraint important in conjunction with decisions concerning the size (design) of a mill. These design considerations were included to indicate that one approach to optimum design (and replacement, as well) can be exactly the same as that used to determine optimum operating conditions.

Because of this mixed cost situation, and because of the somewhat arbitrary way in which revenues, costs, and some restraints were selected, any mathematical model developed for the hypothetical pulping system is highly specific. This, of course, in no way detracts from a demonstration of the general utility of the Operations Research approach. Nor does it detract from any concepts developed in formulating and optimizing the model.

The "measure of effectiveness" for the hypothetical pulping system was chosen to be net dollar return. This is, simply: revenues minus variable costs for the process considered.

THE ECONOMIC OPTIMIZATION OF THE HYPOTHETICAL KRAFT PULPING PROCESS

Development of the Model

It is generally desirable in optimization problems to represent the entire model in mathematical terms prior to optimization. This avoids experimentation involving sequential analysis of intermediate results during the optimization, and the consequent development of only the currently needed portions of the model. With complete prior quantification, the optimization actually can be accomplished more easily, and the model developed will have general utility in circumstances where certain portions of the system change because of temporary operating disruptions, cost and equipment changes, etc. Furthermore, such a model (in contrast to the very limited one developed in a sequential analysis) can often be almost directly incorporated as the framework of a more complete model of the same system, or as a complete portion of a more extensive model of an expanded system.

Need for and Development of a Pulping Rate Expression

Initially, in this study, preliminary material and energy balances indicated that all activities in the

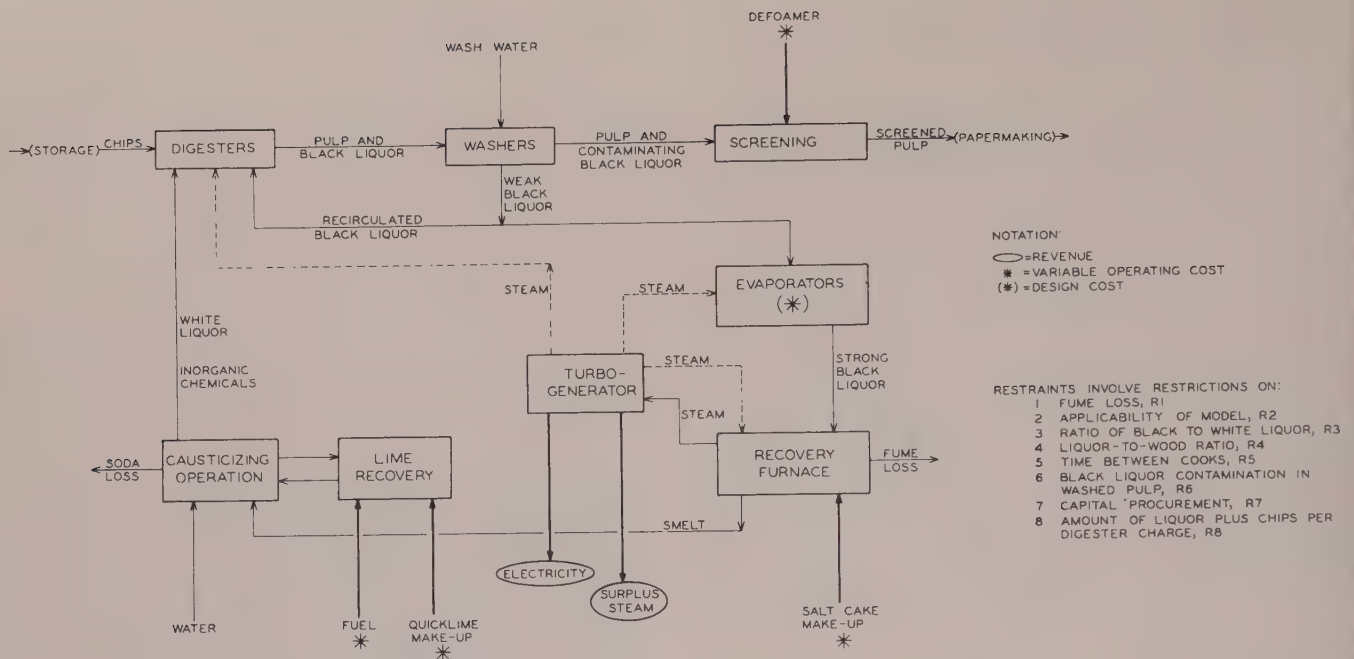

Fig. 2. Simplified flow diagram of hypothetical kraft pulping system

hypothetical pulping process, except the digester operation, were at least potentially capable of being quantified. As will be seen later, for complete prior quantification it is necessary to have an integrable rate expression interrelating all the important kraft cooking variables.

An investigation of the literature revealed the lack of any generally useful rate equation. However, there seemed to be evidence encouraging belief in the existence of such expressions and hinting at how one might be derived.

Consequently, an investigation was undertaken wherein a rate expression appropriate for the economic optimization was developed and experimentally verified. This expression (to within $\pm 0.3\%$) relates the total time of a cook (t_t) to initial digester temperature (T_0), time-up-to-temperature (t_u), maximum temperature (T_m), sulfidity (S), initial concentration (c_i), chemical-to-wood ratio (c_w), permanganate number (K no.), and pulp yield (Y). (The symbols for the variables are given here to allow the interpretation of "Cooking Conditions" in Fig. 3. The significance of this figure will be discussed in the next section.) This particular phase of the work is described in (*1*) and will be the subject of another paper to be presented in the near future.

Formulation of the Mathematical Model from Engineering Balances

As a result of having a rate expression interrelating the important kraft cooking variables and thereby quantitatively describing the digester operation, the entire hypothetical pulping process could be quantified and its mathematical model developed. To do this, it was necessary to take material, energy, and economic balances over the whole system. These engineering balances were based on suitable assumptions and appropriate performance characteristics of the equipment, and for the operations involved. Thus, in addition to the pulping rate expression which describes the cooking operation, dilution curves for washing, steam economies in evaporation, the performance of the recovery furnace and steam turbines, causticizing efficiency in the causticizing operation, and quantitative expressions for the associated costs and revenues were all important factors in the formulation of a comprehensive mathematical model.

A detailed description of the hypothetical pulping system is given in Fig. 3. The quantities indicated on this flow diagram resulted from material, energy, and economic balances based on an arbitrarily chosen, particular set of realistic operating conditions. Reference (*1*) includes a detailed explanation of the assumptions and calculations made. From this specific base case, engineering balances, quantitatively describing and interrelating the operations of the pulping system, were established. These generalized balances, in turn, allowed the development of the mathematical model of the system [see (*1*)]. Table I shows the resulting model of the hypothetical pulping process.

The Nature of the Mathematical Model

Number of Independent Variables. The model of Table I consists of an effectiveness function (revenues minus variable costs); eight realistic, functional restraints; and a number of "subsidiary equations" and parameters. For the hypothetical pulping system considered, there are five more variables in the subsidiary equations (and thus in the effectiveness and restraint functions) than there are subsidiary equations for their determination. Thus, there are *five* independently adjustable variables, and, while they may be arbitrarily chosen in a number of ways, they are defined here as follows:

$Y1$ = total load of inorganic chemical as Na_2O in white liquor before white liquor losses
$Y2$ = volume of white liquor to digesters
$Y3$ = volume of black liquor to digesters
$Y4$ = rate of fresh wash water to washers
$Y5$ = time between cooks at each digester

(Values of these five independent variables for the base case are indicated in Fig. 3.)

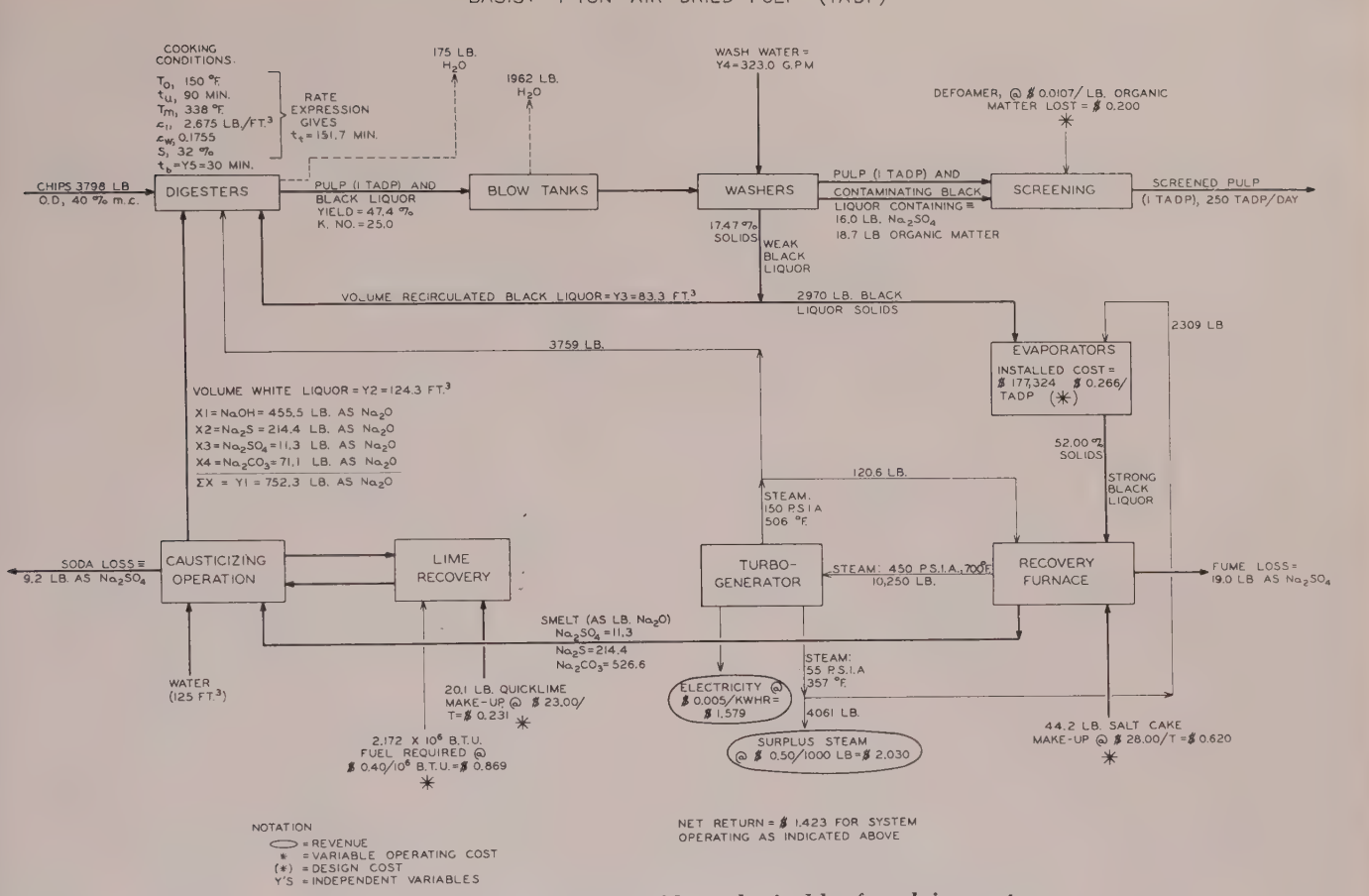
BASIS: 1 TON AIR-DRIED PULP (TADP)
COOKING CONDITIONS.
T_o, 150 °F.
t_u, 90 MIN.
T_m, 338 °F.
ϵ_{ii}, 2.675 LB./FT.^{3}
ϵ_{w_i} 0.1755
S, 32 %
t_b=Y5=30 MIN.
RATE EXPRESSION GIVES t_t = 151.7 MIN.
175 LB. H_2O
1962 LB. H_2O
WASH WATER = Y4=323.0 G.P.M
DEFOAMER, @ $ 0.0107/ LB. ORGANIC MATTER LOST = $ 0.200
CHIPS 3798 LB O.D., 40 % m.c.
DIGESTERS
PULP (1 TADP) AND BLACK LIQUOR YIELD = 47.4 % K. NO. = 25.0
BLOW TANKS
WASHERS
PULP (1 TADP) AND CONTAMINATING BLACK LIQUOR CONTAINING = 16.0 LB. Na_2SO_4 18.7 LB ORGANIC MATTER
SCREENING
SCREENED PULP (1 TADP), 250 TADP/DAY
17.47 % SOLIDS
WEAK BLACK LIQUOR
VOLUME RECIRCULATED BLACK LIQUOR = Y3 = 83.3 FT.^{3}
2970 LB. BLACK LIQUOR SOLIDS
2309 LB
3759 LB.
EVAPORATORS
INSTALLED COST = $ 177,324 $ 0.266/ TADP (*)
VOLUME WHITE LIQUOR = Y2 = 124.3 FT.^{3}
X1 = NaOH = 455.5 LB. AS Na_2O
X2 = Na_2S = 214.4 LB. AS Na_2O
X3 = Na_2SO_4 = 11.3 LB. AS Na_2O
X4 = Na_2CO_3 = 71.1 LB. AS Na_2O
ΣX = Y1 = 752.3 LB. AS Na_2O
52.00 % SOLIDS
120.6 LB.
STEAM, 150 P.S.I.A 506 °F.
STRONG BLACK LIQUOR
SODA LOSS = 9.2 LB. AS Na_2SO_4
CAUSTICIZING OPERATION
LIME RECOVERY
TURBO-GENERATOR
STEAM: 450 P.S.I.A., 700°F. 10,250 LB.
RECOVERY FURNACE
FUME LOSS = 19.0 LB AS Na_2SO_4
SMELT (AS LB. Na_2O) Na_2SO_4 = 11.3 Na_2S = 214.4 Na_2CO_3 = 526.6
WATER (125 FT.^{3})
20.1 LB. QUICKLIME MAKE-UP @ $ 23.00/ T = $ 0.231
STEAM: 55 P.S.I.A 357 °F.
ELECTRICITY @ $ 0.005/KWHR = $ 1.579
4061 LB.
2,172 X 10^6 B.T.U. FUEL REQUIRED @ $ 0.40/10^6 B.T.U. = $ 0.869
SURPLUS STEAM @ $ 0.50/1000 LB = $ 2.030
44.2 LB. SALT CAKE MAKE-UP @ $ 28.00/T = $ 0.620
NOTATION
= REVENUE
* = VARIABLE OPERATING COST
(*) = DESIGN COST
Y'S = INDEPENDENT VARIABLES
NET RETURN = $ 1.423 FOR SYSTEM OPERATING AS INDICATED ABOVE

Fig. 3. Detailed flow diagram of hypothetical kraft pulping system

Effectiveness Function and Restraints as Implicit Functions of the Independent Variables Alone. If values are assigned to the adjustable parameters in the model (Table I), all the components of the effectiveness function and all of the restraints are, by means of the subsidiary equations, defined implicitly in terms of the independent variables (Y's) alone. This can be demonstrated for a typical component of the effectiveness function and a representative restraint by interrelating the selected subsidiary equations displayed in Table II.

The cost of salt cake make-up is considered as a representative and familiar component of the model's effectiveness function. Knowing the cost per ton of salt cake, it is necessary to express the amount of salt cake required, for any given set of operating conditions, as a function of the corresponding independent variables. The amount of salt cake required, M, is expressed in the generalized material balance by equation (15). See Table II. This equation involves, besides the independent variable $Y1$, the two variables L_N and ΣX_a. ($Y1$ is the total load of inorganic chemical as Na_2O in the white liquor, before white liquor losses; L_N is related to the inorganic chemical lost from the washers; ΣX_a is the actual total load of inorganic chemical in the white liquor, before white liquor losses.) Each of the two variables, L_N and ΣX_a, must be expressed ultimately as a function of the Y's only. This is done for L_N by equation (27) which is essentially a dilution curve equation relating L_N to $Y4$ (rate of fresh wash water to washer system).

The quantity, ΣX_a is defined by equation (21), where

$X1$ = NaOH as Na_2O in the white liquor before white liquor losses,
$X2$ = Na_2S as Na_2O in the white liquor before white liquor losses,
$X3$ = Na_2SO_4 as Na_2O in the white liquor before white liquor losses, and
$X4$ = Na_2CO_3 as Na_2O in the white liquor before white liquor losses,

and the numerical coefficients represent the ratio of actual weight to weight as Na_2O for each component.

Equation (21), in conjunction with the following four equations (17–20), defines ΣX_a as a function of the Y's and L_N. [Equation (17) is essentially a causticizing efficiency equation, while equation (18) represents the assumed condition of 95% reduction in the furnace. Equation (19) results from the combination of several material balances, while equation (20) is, in effect, the definition of $Y1$.] As indicated above, L_N is a function of $Y4$ only [see equation (27)], so that by means of the subsidiary equations, M can be expressed as a function of the independent variables alone.

A typical restraint, $R8$ (recognizing a limitation to the amount of chips and liquor that can be put in digesters of a given size), is expressed in the model and in Table II by equation (9). The experimentally verified rate expression gives t_t (total time for a cook) as a function of the kraft cooking variables. In the hypothetical pulping system, some of these variables are constant; the remaining cooking variables, and thus t_t, can be expressed ultimately in terms of the Y's [equation (28)] in a manner similar to that shown for ΣX_a above. Then, since V_L, the total volume of liquor, is, by equation (26), a function of independent variables alone, $R8$ is seen to be expressed essentially in terms of the Y's. [Restraint $R8$ is essential in the system and is one reason the pulping rate expression had to be developed. The "n" in equation (9) is a parameter characterizing the system and so is fixed for a given optimization.]

In this manner, the whole model—that is, all costs and revenues comprising the effectiveness function, and all the restraints considered—can be ultimately expressed in terms of the independent variables alone [equations (29), (30)].

Nonlinear Nature of the Model. The nature of a mathematical model in reference to its optimization (discussed in a following section) is determined by its characteristics when *explicitly* expressed in terms of the independent variables alone. Such explicit expression

Table I: The Model

Basis: 1 Ton of Air-Dried Pulp (TADP)

Effectiveness Function = net return ($) = revenues ($) − variable costs ($) =

$$E = (5.843)(10^{-7})H - (1.170)(10^{-4})I - (2.358)(10^{-5})l - \frac{(l/s - l/0.52)10^{-4}}{1.104 - (0.72)s} - (1.365)(10^{-1}) - (1.502)(10^{-6})C_e - (3.21)(10^{-2})M - (5.08)(10^{-4})X1 - (4.77)(10^{-3})(k_9)X1 - \frac{(37.48)L_N}{(0.995)\Sigma X_a + 1998} \quad (1)$$

Restraints:

$$R1 = K_1 - \frac{(8.3)Y1}{752.3} \geq 0 \quad \text{(fume loss limitation)} \quad (2)$$

$$R^2 = X^2 - \frac{(K_2)X1}{(1 - K_2)} \geq 0 \quad \text{(applicability of Model restriction)} \quad (3)$$

$$R3 = (K_3)Y2 - Y3 \geq 0 \quad \text{(limitation on ratio of black to white liquor)} \quad (4)$$

$$R4 = V_L - K_4 \geq 0 \quad \text{(restriction on liquor-to-wood ratio)} \quad (5)$$

$$R5 = Y5 - K_5 \geq 0 \quad \text{(limitation on time between cooks)} \quad (6)$$

$$R6 = K_6 - \frac{(3496)L_N}{(0.995)\Sigma X_a + 1998} \geq 0 \quad \text{(restriction on black liquor contamination in washed pulp)} \quad (7)$$

$$R7 = K_7 - C_e \geq 0 \quad \text{(capital procurement limitation)} \quad (8)$$

$$R8 = \frac{n(15{,}553)}{t_i + Y5} - 110.6 - V_L \geq 0 \quad \text{(limitation to the amount of liquor plus chips per digester charge)} \quad (9)$$

In addition: All independent variables ($Y1$, $Y2$, $Y3$, $Y4$, $Y5$) ≥ 0. The economics of the process makes mathematical statements of these "nonnegativity" restraints unnecessary.

Subsidiary Equations:

$$H = (1.413)(10^7) - (1328)\Sigma X_a - (531)\Sigma X_s + \frac{[(2324)\Sigma X_a - (2.874)(10^7)]L_N}{(0.995)\Sigma X_a + 1998} \quad (10)$$

$$I = 3623 + (64.4)Y2 + (58.4)Y3 + \frac{n(36{,}578)}{t_i + Y5} \quad (11)$$

$$l = (0.995)\Sigma X_a + 1998 - (1.75)L_N \quad (12)$$

$$s = l/[(0.995)\Sigma X_a + (60.8)Y2 + (48)Y4 - (0.1121)I - 5095] \quad (13)$$

$$C_e = 148{,}000 - (331{,}000)s + (40)l - (61)sl \quad (14)$$

$$M = \frac{(12.3)Y1}{752.3} + \frac{(1.75)L_N(0.995)Y1}{(0.995)\Sigma X_a + 1998} \quad (15)$$

$$L_N = \frac{k_6}{(0.024)Y4 - k_7} + k_8 \quad (16)$$

$$X1 = \left\{k_1 - [(4.782)(10^{-2})(Y1 - X3) + (1.956)(10^{-1})(Y1 - X3)^2/Y2 + (6.376)(10^{-1})X2 + (1.594)X3]\frac{1}{(100)Y2}\right\}(Y1 - X2 - X3) \quad (17)$$

$$X2 = (19)X3 \quad (18)$$

$$X3 = \frac{(3.535)(10^{-4})(Y1)^2 + (5.311)(10^{-1})Y1 + (8.705)(10^{-2})L_N(Y1)}{(5.2)(10^{-2})Y1 + 78 + (2.377)(10^{-3})L_N(Y1)} \quad (19)$$

$$X4 = Y1 - (X1 + X2 + X3) \quad (20)$$

$$\Sigma X_a = (1.290)X1 + (1.258)X2 + (2.290)X3 + (1.710)X4 \quad (21)$$

$$\Sigma X_s = (1.710)Y1 - (4.52)(10^{-1})X2 + (5.80)(10^{-1})X3 \quad (22)$$

$$t_i = \frac{k_2}{c_i - k_3\frac{c_i}{c_w} - k_4} + k_5 V_L \quad (23)$$

$$c_i = \frac{(X1 + X2)(0.995)}{V_L} \quad (24)$$

$$c_w = \frac{(X1 + X2)(0.995)}{3798} \quad (25)$$

$$V_L = Y2 + Y3 + 41.6 \quad (26)$$

Parameters:

fixed parameters:

- $k_1 = 0.950$
- $k_2 = 96.82$
- $k_3 = 0.0663$
- $k_4 = 0.3153$
- $k_5 = 0.321$
- $k_6 = 12.5$
- $k_7 = 4.62$
- $k_8 = 12.0$

- $K_1 = 10.0$, maximum allowable fume loss = 10 lb./TADP
- $K_2 = 0.28$, minimum sulfidity allowable for Model to be applicable = 28%
- $K_3 = 1.5$, maximum ratio of black to white liquor = 1.5
- $K_4 = 213.1$, minimum allowable liquor-to-wood ratio = 3.5 ml./g.
- $K_5 = 25.0$, minimum time required between cooks = 25 min.

Parameters adjustable for the purpose of model alteration:

- k_9 = cost of lime kiln fuel, $/10^6 B.t.u.
- n = number of digesters
- K_6 = maximum allowable black liquor contamination in washed pulp, lb. B.L. organic matter/TADP
- K_7 = maximum capital available for purchasing evaporators, $

can be accomplished for the pulping system model of Table I by actually carrying out the process discussed in the preceding section. Doing this, the effectiveness function and four of the restraints (*R*2, *R*6, *R*7, and *R*8) are seen to be complicated nonlinear functions of the independent variables (*Y*'s). Thus, the overall model is classified as *nonlinear*. More descriptively, the model represents a *nonlinear, restrained* system.

Adjustable Parameters. The adjustable parameters were incorporated in the model to provide for flexibility in the optimization studies. Their use in this connection is discussed under "Results of Optimizing the Hypothetical Pulping System."

NOMENCLATURE FOR VARIABLES IN MODEL OF TABLE I

C_e = installed cost of evaporators, dollars
c_i = initial active alkali concentration, lb./cu. ft.
c_w = initial active alkali-to-wood ratio, lb./lb.
E = measure of effectiveness (net return), dollars/TADP
H = heat in gross high-pressure steam generated, B.t.u./TADP
I = water equivalent of digester and contents, lb./TADP
l = black liquor solids load to furnace, lb./TADP
L_N = unadjusted soda loss (as Na_2SO_4) from washers, lb./TADP
M = salt cake make-up (as Na_2O), lb./TADP
R_i = restraints
s = weight fraction solids in black liquor to evaporators and black liquor recirculated to digesters, lb./lb.
t_t = total time for a cook, min.
V_L = total volume of white and black liquors and moisture in chips, cu. ft./TADP
$X1$ = NaOH as Na_2O in white liquor before white liquor losses, lb./TADP
$X2$ = Na_2S as Na_2O in white liquor before white liquor losses, lb./TADP
$X3$ = Na_2SO_4 as Na_2O in white liquor before white liquor losses, lb./TADP
$X4$ = Na_2CO_3 as Na_2O in white liquor before white liquor losses, lb./TADP
$Y1$ = total load of inorganic chemical as Na_2O in white liquor before white liquor losses, lb./TADP
$Y2$ = volume of white liquor to digesters, cu ft./TADP
$Y3$ = volume of black liquor to digesters, cu. ft./TADP
$Y4$ = rate of fresh wash water to washers, g.p.m.
$Y5$ = time between cooks, min.
ΣX_a = actual total load of inorganic chemical in white liquor before white liquor losses, lb./TADP
ΣX_s = actual total load of smelt from recovery furnace unit, lb./TADP

Optimization

The optimization of the mathematical model representing the hypothetical pulping system constituted the final phase of this work. Optimization consists of the determination of the values or the model's independent variables (*Y*'s) which maximize the effectiveness function subject to nonviolation of the restraints.

Optimizations can be accomplished in a number of ways depending on the particular nature of the effectiveness function, the presence or absence of restraints, the nature of the restraints when present, the dimensions and complexity of the problem, the accuracy desired in the final solution, etc. (In addition, when computers are used, computer speed and storage capacity are considerations.)

Thus, when the effectiveness function and any restraints involved are linear, standard methods of "linear programming" can be used to seek an optimum. On the other hand, a general case for optimization occurs when the effectiveness function and at least some of the restraints are relatively complicated, nonlinear expressions. The pulping system model considered here is an example of this general case. Such nonlinear situations have considerable industrial importance.

Some Approaches to the Optimization of Nonlinear Systems. When the effectiveness function is nonlinear and subject to *no* restraints (this probably seldom happens in realistic situations), the approximate gradient technique of the Method of Steepest Ascents can be used to seek an optimum (*13*). (If dimensionality is not too great, ordinary calculus can be used.) The Method of Steepest Ascents allows for the approximate calculation of the steepest path up to the top of the effectiveness surface so that the maximum is arrived at very efficiently. The thin, solid line in Fig. 4 indicates, for a three-dimensional case [$E = \mathrm{E}(X_1, X_2)$], this path (I, 4, 5, 2, 1) which, ideally, is always perpendicular to the contour lines (lines of constant E). Point I is an arbitrarily chosen starting point.

When restraints involving inequalities apply, Lagrange multipliers may be used in smaller problems

Table II. Equations Indicating how Model Can Be Expressed in Terms of the Independent Variables Alone

$$M = \frac{(12.3)Y1}{752.3} + \frac{(1.75)L_N(0.995)Y1}{(0.995)\Sigma X_a + 1998} \tag{15}$$

$$L_N = \frac{12.5}{(0.024)Y4 - 4.62} + 12.0 \tag{27}$$

$$\Sigma X_a = (1.290)X1 + (1.258)X2 - (2.290)X3 + (1.710)X4 \tag{21}$$

$$X1 = \left\{0.950 - \left[(4.782)(10^{-2})(Y1 - X3) + (1.956)(10^{-1})(Y1 - X3)^2/Y2 + (6.376)(10^{-1})X2 + (1.594)X3\right]\frac{1}{(100)Y2}\right\}(Y1 - X2 - X3) \tag{17}$$

$$X^2 = (19)X3 \tag{18}$$

$$X3 = \frac{(3.535)(10^{-4})(Y1)^2 + (5.311)(10^{-1})Y1 + (8.705)(10^{-2})L(_NY1)}{(5.2)(10^{-2})Y1 + 78 + (2.377)(10^{-3})L_N(Y1)} \tag{19}$$

$$X4 = Y1 - (X1 + X2 + X3) \tag{20}$$

$$R8 = \frac{n(15{,}553)}{t_t + Y5} - 110.6 - V_L \geq 0 \tag{9}$$

$$t_t = f(Y1, Y2, Y3, Y4, Y5) \tag{28}$$

$$V_L = Y2 + Y3 + 41.6 \tag{26}$$

$$E = \text{Effectiveness} = \text{Revenues} - \text{Costs} = \mathrm{E}(Y1, Y2, Y3, Y4, Y5) \tag{29}$$

$$R_i = i^{\text{th}}\ \text{Restraint} = R_i(Y1, Y2, Y3, Y4, Y5) \geq 0, \qquad i = 1, 2\ldots\ldots, 8 \tag{30}$$

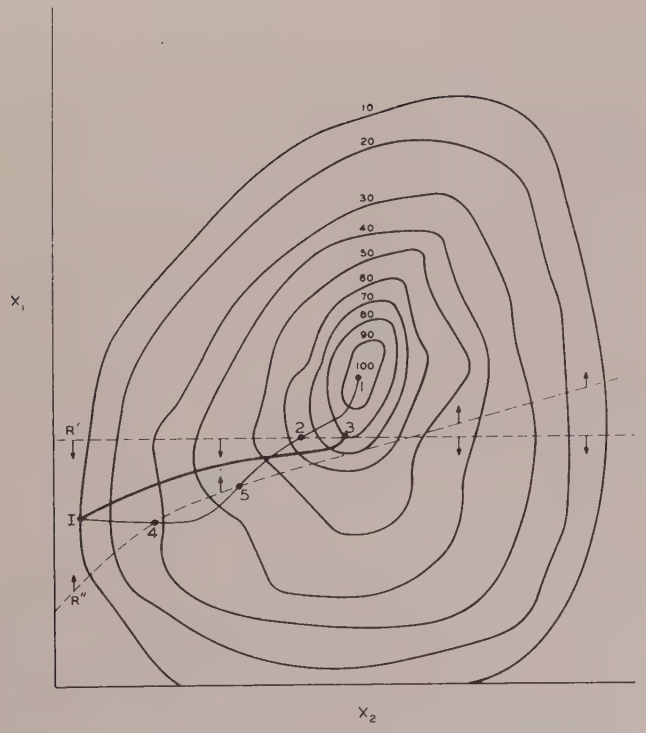

Fig. 4. Contour diagram of $E = E(X_1, X_2)$ showing paths of ascent and restraints

(*2, 14, 15*). For larger ones, one approach is to apply the Method of Steepest Ascents until a limiting value of a restraint is reached. From this point on, an efficient procedure depends upon the nature of the model—in particular, the nature of restraints. Thus, when a single restraint is involved, like R' (which represents a maximum value for the independent variable X_1) in Fig. 4, the optimization may be completed by moving in the direction of steepest ascent with this variable held constant at its limiting value. The overall path of the optimization then becomes I, 4, 5, 2, 3. (The arrows from the dashed restraint boundaries in Fig. 4 point into the region of allowable solution.)

However, suppose a single restraint, R'' (a more complicated functional restraint), is involved (again, see Fig. 4). Following the path of steepest ascent soon results (at point 4) in a violation of this boundary. Using the approximate gradient method alone, one might proceed farther up the path of steepest ascent in hopes that the restraint would become noncritical at the optimum (as actually happens in the illustration). But in a more complex problem, since neither the nature of the effectiveness surface nor that of the restraints may be known, this is risky.

As another approach to the above situation, it is possible, by means of a series of linear approximations to the nonlinear effectiveness and restraint surfaces, to apply linear programming sequentially (*16*). But this generally useful approach can be somewhat inefficient in certain circumstances.

Still other techniques, such as a combination of linear programming and "search" theory (*17*) and the Monte Carlo method have been suggested or used in certain complex nonlinear situations.

As part of the present work, a new approach to optimization of nonlinear, restrained systems was devised. With both restraints applying in Fig. 4, this new approach follows a modified path of ascent (heavy, solid line) which, while maximizing E as quickly as possible, at the same time automatically steers clear of the restraints and thus prevents their violation. At the very optimum, however, solutions are allowed on critical restraint surfaces. Essentially, this new approach is based on steepest ascents up a succession of *created* response surfaces, *within* the *natural* "solution space." This *Created Response Surface Technique* for solving optimization problems is discussed in (*1*) and will be the subject of a separate paper to be presented in the near future.

A program using the new approach to optimize the system considered in this paper was developed and successfully run on an IBM 650 digital automatic computer.

Results of Optimizing the Hypothetical Pulping System

A number of parameters (like the "n" in $R8$) were built into the pulping system model (see Table I). These parameters are related to raw material costs and changed limitations on restraints. Their adjustment provided for an easily changed model corresponding to a somewhat different system.

The amount of improvement in effectiveness resulting from an optimization depends on the nature of the model, the amount of production from the system, and the starting point (corresponding, perhaps, to current operating conditions in a real mill).

In this study, several optimizations were accomplished for hypothetical systems having changed values of some of the parameters and different initial operating conditions. One such optimization (where fairly poor initial conditions were purposely chosen and the optimum was not highly restrained) indicated a $98,000-per-year increase in net return for a 250 ton per day operation. For another system (where the initial conditions were more carefully selected and the critical restraints were more restrictive) a $55,000-per-year improvement occurred. It is to be emphasized that these gains are significant only in relationship to the particular system involved.

CONCLUSIONS

A very important contribution of O.R. is the development of a reserved yet confident reliance on results of studies of isolated "subsystems." These subsystems—usually far too complex for intuition alone to comprehend—represent only a portion of the overall system. Yet, developing even simplified subsystem models and obtaining appropriate solutions can uncover vastly improved operating conditions. In addition, many important indirect benefits result, such as a much better understanding of the system involved, an indication of where and what kind of modification can be made to improve the system, and the possibility of using the model developed in a more comprehensive system representation.

Operations Research provided a very effective approach to the economic optimization of the hypothetical kraft pulping process considered in this paper. In extending this approach to actual industrial kraft pulping processes, there are indications that additional infor-

mation on the kinetics of kraft pulping, better process control, and other requirements would be necessary. Only by actual application of the O.R. approach to a particular pulping system do specific requirements become apparent and serve to focus attention, in a new way, on needed areas of investigation.

A goal of O.R. is to be able to accurately represent a complete industrial operation quantitatively, in a form amenable to optimization. By linking together carefully developed models of the subsystems which comprise the overall system, this ideal goal can be approached.

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Fractionation of Hemicelluloses

RUSSELL NELSON

Hemicelluloses were fractionally removed from slash pine chlorite holocellulose by stepwise alkaline extraction. Xylan was found to be concentrated more in the earlier than in the later fractions removed, whereas glucomannan exhibited opposite behavior. It is considered that the composition of the extracted fractions is controlled by differences in the two main polysaccharide systems with respect to molecular properties, position in the cell wall structure and probably degree of association with cellulose. Subfractions were separated from extracted fractions by a novel method consisting of sequential addition of cetyl pyridinium bromide, borax and acetone to aqueous solutions of the hemicelluloses. Other subfractions were separated by copper complexing followed by alkaline extraction. It was possible by these methods to prepare xylan and glucomannan with varying efficiency having purities generally above 90%.

The hemicelluloses exist in nature as polysaccharide mixtures of varying heterogeneity. In the course of any rigorous characterization of these natural mixtures, there are three separate and essential stages. (a) *Isolation* from a suitable plant source, (b) *fractionation* into homogeneous components, and (c) *proof of structure* of the individual components (*1*). Methods for isolation and proof of structure have been reasonably well developed as evidenced by an abundance of pertinent literature (*1–4*), but comparatively little has been reported on fractionation. As a result, progress in hemicellulose characterization has been limited.

Fractionation by precipitation and extraction processes depends on solubility differences between the components. With the hemicellulosic polysaccharides, solubility may be variably influenced by average molecular weight, distribution of molecular weights, shape, type and configuration of functional groups, homogeneity of composition and relationships between the cell wall components. Consequently, fractionation should not be expected to be governed by any single one of these solubility factors but instead by an average of the plus and minus features of several of them operating simultaneously during the fractionation process. It is apparently for this reason that overlapping or tailing of fractions is experienced, and it is only by the most tedious and painstaking procedures that high purities are usually achieved and then often by large sacrifices in yield.

Ordinarily, fractionation by extraction is not as efficient as by precipitation from homogeneous solution. This is because dissolution is controlled more by accessibility, diffusion, membrane barriers, swelling restrictions, etc., than by molecular properties. In extraction processes the more highly branched and heterogeneously composed hemicelluloses are usually removable with dilute alkaline solutions (*5–8*), whereas a

Russell Nelson, Research Chemist, Buckeye Cellulose Corp., Memphis, Tenn.

more homogeneous polysaccharide is removable by subsequent extraction with stronger alkali (*5*, *9*). Delignification before extraction may or may not be necessary, depending on the plant source (*5*, *10*).

Various preswelling treatments of the plant source may alter the composition of fractions removed in the main extractions (*11-13*). The addition of borate salts to alkaline extractants has been used frequently to facilitate removal of mannans (*14*), presumably by means of the complex formed between borate ion and *cis* hydroxyls. Recently, Lindberg and Meier (*9*) combined the action of preswelling and borates to isolate several glucomannans of notable purity. Of particular interest in their work was the separation of a glucomannan from exhaustively extracted holocellulose residues following destruction of the biological structure by regeneration from cupriethylenediamine. Treiber (*15*), on the other hand, successfully reduced "resistant" hemicelluloses markedly by the simple addition of beryllium hydroxide to the alkaline extractant.

Hemicellulose mixtures in the isolated as well as in the native state may be partially resolved by fractional extraction. Thus, Hamilton and Thompson (*16*) separated glucuronoxylan and glucomannan by prolonged extraction of sulfite hemlock pulp hemicelluloses with dilute alkali, employing to advantage the acidic and branched character of the xylan. Softwood xylans in purities much above 50 to 60% are generally obtained with difficulty by extraction methods.

Ball, Jones, Nicholson, and Painter (*17*) separated a mixture of loblolly pine hemicellulose acetates into pure glucuronoxylan and galactoglucomannan fractions by distribution between chloroform and aqueous carbonate. This is probably the only instance in which a standard organic separation technique has been used to resolve a polysaccharide mixture.

As indicated above, fractionation by precipitation is more efficient than by extraction. What may be considered the classical precipitation scheme consists of acidifying an alkaline solution of hemicelluloses to obtain one precipitate and then flooding the supernatant with some water-miscible solvent, such as acetone or alcohol, to obtain a second precipitate. As a rule, neutral and linear or moderately branched polysaccharides are found in the first fraction while acidic and more highly branched polysaccharides are found in the second. Several refinements of this basic scheme have been developed over the past 25 years. One of these was recently developed by Immergut and Ranby (*18*) to isolate from a sulfite spruce pulp extract glucuronoxylan and glucomannan in about 92 and 95% purity, respectively.

Some resolutions have been performed by fractionally precipitating the acetylated and methylated derivatives of polysaccharide mixtures from chloroform or acetone solution with petroleum ether, but the sharpness of separation is less than that desired (*19–21*).

The differential solubility of the copper-polysaccharide complexes in alkali has proved useful in purification and fractionation (*14*, *17*, *22–25*). Polysaccharides containing mannose (i.e., mannans, glucomannans, galactoglucomannans and galactomannans) form complexes with cupric ions under certain conditions. Ordinarily, these complexes are less soluble than those formed from xylans and glucans. Using this principle, Timell and Tyminski (*24*) isolated a glucomannan by extracting xylan from a copper complex of white spruce hemicellulose by replicate alkaline treatments. Similarly, Adams (*25*) used the copper technique to obtain a galactoglucomannan from the water extract of spruce wood.

Ammonium sulfate has been used with some success to isolate xylan-rich fractions (*21*, *26*), and Meier (*27*) and Hamilton (*28*) have recently shown that barium hydroxide precipitates glucomannan with a fair degree of selectivity.

Scott (*29*) and Stacey and Barker (*30*) were among the first to demonstrate that proteins and acidic polysaccharides like chondroitin sulfate, heparin, hyaluronic acid, alginic acid and pectin, react with certain quaternary ammonium compounds like cetyl trimethyl ammonium bromide and cetyl pyridinium bromide, to form salts which are poorly soluble in slightly acid to strongly alkaline media (*29*). Neutral polysaccharides such as glycogen, dextran, and the blood group polysaccharides remain predominantly in solution. Subsequently, some neutral polysaccharides like yeast mannan, ivory nut mannan, and laminarin were also shown to be precipitable with the quaternary bases if the precipitation is performed in the presence of borate ion under alkaline conditions (*31*, *32*). It is believed that acidity is conferred on the neutral polysaccharide by virtue of the borate ester or complex, since principally those polysaccharides having *cis* hydroxyls in their normal structure form the insoluble amine salts. In view of the encouraging results obtained by fractionating miscellaneous polysaccharides with quaternary ammonium salts, it seemed of particular interest to determine whether such a method could also be employed to resolve wood hemicellulose mixtures.* The hemicelluloses of slash pine, *Pinus caribaea*, were selected as especially suited for this determination since they are composed of acidic and neutral mannan-type polysaccharide systems (*8*, *33–36*). A series of crude hemicellulose fractions were obtained by graded alkaline extraction of chlorite slash pine holocellulose. These were fractionally precipitated with cetyl pyridinium bromide before and after borate salt addition, with acetone and with copper salt.

EXPERIMENTAL

Holocellulose Preparation

Holocellulose was prepared from alcohol-benzene extracted 20 to 40-mesh slash pine wood meal as described by Wise (*37*). Klason lignin, 5.5%; ash, 1.4%; yield, 76.5%, dry wood basis.

Alkaline Extractions

Nine hundred grams of holocellulose were successively extracted with 9 l. each of 3, 10, and 18% NaOH and then with 18% NaOH to which had been added 5% H_3BO_3. Extractions were run under nitrogen for 3 hr. at 25 ± 1°C. with constant stirring. Following each extraction, the liquors were filtered through cheese cloth pre-extracted with alkali and then through fritted glass of medium porosity. The insoluble residue was

* Since completion of the present work, two papers have appeared in which cetyl trimethyl ammonium bromide was used with borate salts to fractionate the hemicelluloses of Western larch and Scotch pine. Cf. H. C. Sp., Bouveng and B. Lindberg, *Acta Chem. Scand.* 12, 1977 (1958) and H. Meier, *Acta Chem. Scand.* 12, 1911 (1958).

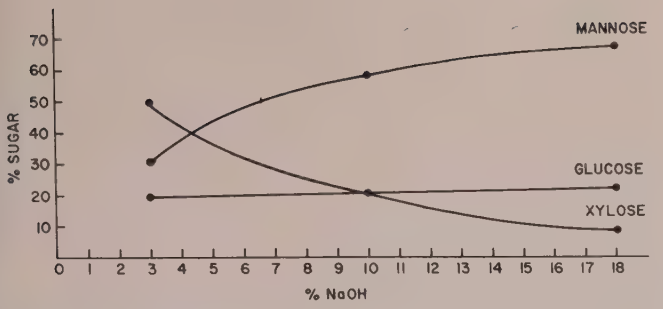

Fig. 1. The effect of alkali concentration on the composition of hemicelluloses successively extracted from slash pine holocellulose at 25°C., 3 hr., 10 : 1, liquor : solid

washed under nitrogen for 30 min. with 4 l. of fresh alkali of the same strength as used in the main extraction.

Isolation of Hemicellulose Fractions

The alkaline extracts were combined with their respective wash liquors after filtration, cooled to 5°C. with ice, acidified to pH 4 to 5 with 98% acetic acid (no precipitation), and the hemicelluloses precipitated with 4 volumes of acetone. The hemicelluloses were collected on the centrifuge and washed repeatedly with 4:1 acetone: water to remove salt, with pure acetone and finally with dioxane. The hemicelluloses were isolated as off-white powders by freeze drying from freshly distilled dioxane. The fraction extracted with 18% NaOH + 5% H_3BO_3 and subfractions contaminated with borax were treated with boiling methanol to remove borate ion.

The yields are given in Table I and are expressed as per cent of holocellulose on an ash-free basis.

Fractional Precipitation

Hemicellulose fractions were dissolved in hot water (60–70°C.) or in alkali (4%) to 1% concentration. A 1% aqueous solution of technical grade cetyl pyridinium bromide was added to the hemicellulose solution at room temperature until precipitation was complete. Further addition of precipitant had no visible effect. After separating the insoluble salt on the centrifuge, the supernatant liquid was stirred with an equal volume of 1% borax solution and enough 1% cetyl pyridinium bromide added to complete precipitation of the second subfraction. After separating this second insoluble salt by filtration through Whatman no. 40 paper, the supernatant liquid was flooded with 4 volumes of acetone to precipitate a third subfraction. The sticky- to curd-like yellow-brown precipitates were kneaded thoroughly on the funnel while washing with 1 to 2 l. of water. The polysaccharides were recovered by dispersion in 5% HCl-5% CH_3COOH dissolved in ice cold 3:1 acetone:water and collected on the centrifuge. The polysaccharides were washed with acetone-water, borates were eliminated where required by methanol extraction, and the subfractions were dried from pure acetone or fractionated further as indicated with CPB-borax-acetone or with Fehling's solution (*24*). The yields are given in Fig. 2 to 4 and are expressed as per cent of the holocellulose on an ash-free basis.

Table I. Properties of Extracted Hemicellulose Fractions and Holocellulose Residue

	Hemicellulose, %, extracted with:				
	3% NaOH	*10% NaOH*	*18% NaOH*	*18% NaOH +5% H_3BO_3*	*Extracted residue*
Glucose + Galactose[a]	19.4	20.3	22.2	24.5	89.5
Mannose[a]	31.1	58.9	68.2	70.2	8.7
Xylose[a]	49.5	20.8	9.6	5.3	1.8
Ash,[b] %	15.4	24.4	31.2	5.0	2.1
Yield,[c] %	11.1	14.0	5.3	2.0	ca. 50
$[\eta]_{c(dl./g.)}$	0.59	0.79	0.75	0.89	..

[a] Calculated as per cent of neutral sugars.
[b] Calculated on dry weight of crude sample.
[c] Calculated as ash-free sample, based on holocellulose.

Carbohydrate Analyses

Carbohydrates were determined, in duplicate, according to the paper chromatography method described

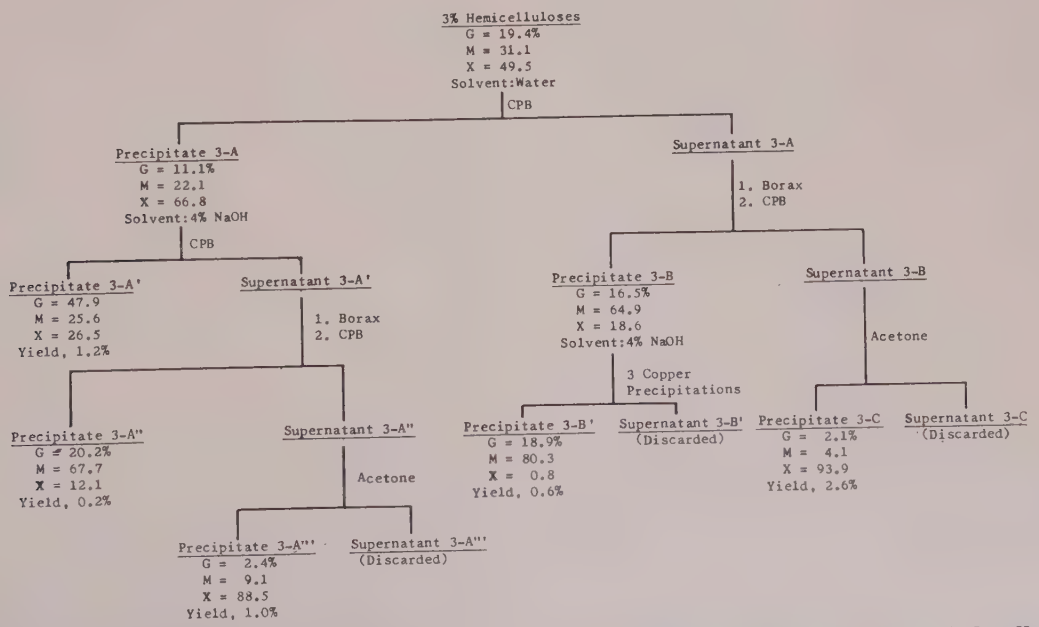

Fig. 2. Fractionation of 3% hemicelluloses; yields calculated as ash-free samples, based on holocellulose

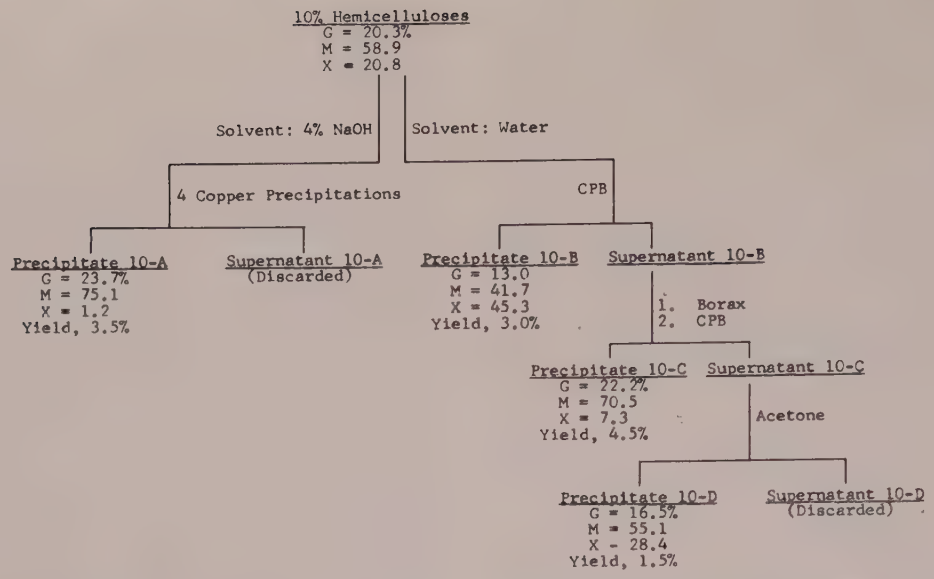

Fig. 3. Fractionation of 10% hemicelluloses; yields calculated as ash-free samples, based on holocellulose

by Durso and Paulson (*38*). Galactose and glucose were estimated together. Arabinose was not estimated, although it was present in minor amounts. Analyses are expressed as the per cent of glucose + galactose, mannose and xylose measured on the chromatogram. Qualitative analyses of chromatograms developed with the upper phase of a ethyl acetate: pyridine:water (2:1:2 by vol.) mixture showed that galactose was present in each of the hemicellulose fractions extracted from the holocellulose, but the proportion decreased toward the end of the extraction sequence. If all galactose units are associated with the same polymer as mannose and hemicellulosic glucose (*17*, *25*), the above observation might suggest the presence in slash pine of a complex galactoglucomannan polysaccharide system (*28*, *36*).

Intrinsic Viscosities

Intrinsic viscosities were determined in duplicate in *M*-cupriethylenediamine at 30 ± 0.02°C. using a dilution viscometer. Concentrations were figured on an ash-free basis, but viscometry was performed at comparable ash levels by addition of sodium acetate where needed. Specific viscosities were measured at 0.40, 0.266, 0.160, and 0.100 g. per dl. The viscometer had an outflow time of 238 sec. for pure solvent.

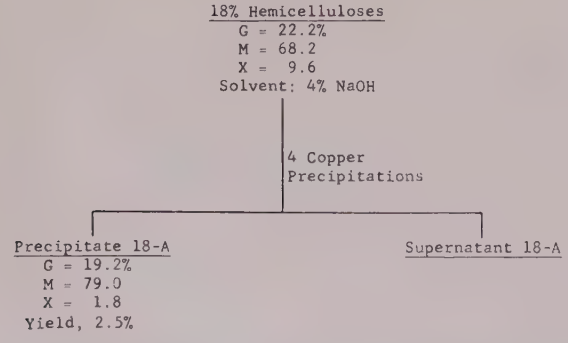

Fig. 4. Fractionation of 18% hemicelluloses; yields calculated as ash-free samples, based on holocellulose

DISCUSSION

From Fig. 1 and Table I, it is evident that the stepwise extraction resulted in partial fractionation. Thus, the xylose concentration is high (*ca.* 50%) in the first fraction removed and it decreases regularly thereafter. The mannan concentration, in contrast, is low in the first fraction removed and increases in subsequent fractions. It has become almost traditional for workers to interpret such extraction data in terms of differences in the degree of order in which the hemicellulosic polysaccharide systems exist either with themselves or with cellulose. We find little or no cause to deviate from this established hypothesis to explain the data in Table I and Fig. 1. On the contrary, studies in these laboratories of xylan, glucomannan, mixtures thereof and extracted residues as related to crystallinity, structure, and probable position within the cell-wall framework have yielded good support for such an association (*39*). Meier (*40*), on the other hand, has recently offered data which could be interpreted as evidence against association between polysaccharide systems. However, it is important to regard fractional extraction behavior in the light of a multiplicity of factors rather than of any single factor like crystallinity. The extraction data in the present work provide a case in point. According to Table I, fractionation by chain length is indicated, but it would be difficult to explain the curves in Fig. 1 on this basis alone. It appears, therefore, that the composition of the extracted fractions is controlled by a combination of molecular properties (including chain length), position in the cell wall and probably degree of association between the two major hemicellulose polysaccharide systems and cellulose.

The subfractionation schemes for the 3, 10, and 18% NaOH fractions are given in Figs. 2, 3. and 4, respectively. Further separation of the 18% NaOH + 5% H_3BO_3 fraction was not attempted. In Figs. 2 and 3 it may be noted that with one exception the addition of cetyl pyridinium bromide (CPB) to aqueous solutions of the hemicelluloses precipitates subfractions which are substantially enriched in xylan (*cf.* 3-A and 10-B). On the basis of the work by Scott (*29*), Stacey and Bar-

ker (*30*) and Hamilton (*36*) such precipitates almost certainly are products of the reaction between CPB and glucuronic acid side groups on the xylan chain. Precipitate 3-A′ is exceptional in that it contains less xylan than subfraction 3-A from which it was derived. Apparently, the electrolyte concentration in the 4% NaOH solvent was sufficiently high to retard precipitation (*29*).

Table II. Mannose: Glucose Ratios of Hemicellulose Fractions

Fraction	Mannose Glucose + Galactose	Fraction	Mannose Glucose + Galactose
3%	1.60	10%	2.90
3-A	1.99	10-A	3.17
3-A′	0.53	10-B	3.21
3-A″	3.35	10-C	3.18
3-A‴	3.79	10-D	3.34
3-B	3.93	18%	3.08
3-B′	4.24	18-A	4.12
3-C	1.95	18 + 5%	2.86

Following separation of the crude xylans, the addition of borax and more CPB to the supernatant liquors precipitates a second set of subfractions which are distinguished by increased mannan concentrations (*cf.* 3-A″, 3-B, and 10-C). These latter precipitates probably result from glucomannans reacting with borax and forming metastable anionic polyelectrolytes which then react with CPB (*31*, *32*).

After separation of the crude xylans and mannans described above, a third set of subfractions are isolable from the supernatant liquors by flooding with acetone (*cf.* 3-A″, 3-C, and 10-D). It is interesting to note from Figs. 2 and 3 that these contain substantial amounts of xylan, particularly 3-A‴ and 3-C, which were not precipitated on addition of the first portion of CPB. Factors responsible for this apparent dual character of slash pine xylan could be due to normal variation in molecular weight, uronic acid content or degree of branching.

As indicated in Figs. 2, 3, and 4, fractional precipitation of select hemicelluloses with Fehling's solution followed by dilute alkaline extraction (*24*) enabled the isolation of glucomannas to contaminate with only 1–2% xylan (*cf.* 3-B′, 10-A, and 18-A). While this method requires prolonged periods of extraction and frequent handling, it is apparently still more efficient for preparing glucomannan than is fractional precipitation with CPB and borax. The expediency and versatility of the latter method, however, cannot be discounted.

Composition was used in the present work as the criterion of purity, assuming that in glucomannans such as are believed to have been separated here the mannose:glucose ratio of 3–4:1 is normal (see Table II). Even if this assumption is correct, purity may not necessarily be tantamount to homogeneity. It was undetermined, for example, that all of the glucomannans (or xylans) separated were structurally equivalent. It is for this reason that the components of the hemicelluloses are to be regarded as polysaccharide systems rather than as simple polysaccharides. Similarly, if the above assumption is incorrect, it was undetermined that the glucomannans were free from contamination by small amounts of cellulose carried over from the holocellulose extraction.

CONCLUSION

Fractionation with quaternary ammonium compounds can be used to resolve wood hemicellulose mixtures. Apparent limitations of the method would be absence of acidic functions and *cis* hydroxyls, similarity of important functions on otherwise dissimilar polysaccharide types, low sensitivity of polysaccharide to precipitant and possibly very low molecular weight. Advantages of the method seem to be expediency and versatility, and on this basis it should serve to complement conventional fractionation methods.

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Dielectric Properties and Moisture Content Determination in Paper

J. VITINS

This paper introduces a new method for determining the moisture content in moving paper. It shows that a single measurement of capacitance, resistance or dielectric loss does not give a true measure of moisture content. Other factors such as variations of temperature, basis weight of paper, relative humidity of air, etc., must be taken into account. The possibility of combining several measurements for automatic moisture control is discussed and optimum frequencies for different dielectric measurements are indicated.

THE considerations described below are aimed at developing a method of automatic moisture control in moving paper during its manufacture. Possible application to other fields is stated only as an illustration.

It is generally known that dielectric properties of a hygroscopic web are functions of relative moisture content, temperature, and composition of the sample. In addition to this the applied measurement techniques require knowledge of the basis weight of the sample.

Assuming that the composition of material is constant and the equipment is error free, it follows that, in general, any dielectric measurement to determine moisture content* has to be accompanied by simultaneous measurements of basis weight and temperature. Consequently an automatic moisture content control would require the combination of a minimum of three simultaneous measurements.

Further analysis of properties of paper and electrode systems will show that the number of the variable parameters is generally more than three and only by absorption measurements at optimum frequencies can the number be reduced to the idealized scheme given above. Following this analysis the study is extended to combinations of the different dielectric measurements available for determination of all three variables, moisture content, basis weight, and temperature. The number of technically acceptable combinations at present is very limited, mainly by the sensitivity of electrodes to gap variations. The possibility of compensation for undesirable effects is demonstrated by the example of waveguide cavity.

PROPERTIES OF PAPER

The resistance of paper to d.c. and a.c. can be utilized for moisture determination in stationary samples. The accuracy and limitations of such measurements are very completely described by Hardacker and Rawcliffe (*1*) and by Hart and Gallay (*2*).

If the paper moves the relations will be different. The conductivity will be overshadowed by charging currents of geometrical and internal capacitances shown in Fig. 1. The paper movement can be considered as replacing the d.c. by a.c. of a proper frequency. For example, paper speed of 1500 f.p.m. with 1-in.-wide electrodes would correspond to a frequency of 600 cycle per sec. The apparent resistance will represent the total dielectric losses in the material.

Figure 2 shows the variation of apparent resistance calculated from dissipation-factor measurements at different frequencies published by Veith (*3*). It shows that resistance measurements on a standing sample cannot be transferred to a moving one.

The frequency spectrum of a dielectric material is shown in Fig. 3. The changes of dielectric properties are explained by changes in polarization. With increase of frequency, different types of polarization decrease rapidly in the different frequency regions.

Interfacial or Ionic Polarization. This appears only in heterogeneous materials as a result of an accumulation of charges at the interfaces of components having different dielectric properties. The cellulose fibers are practically nonconductive. The conductivity of the moisture layer along the fibers is known to be quite variable (*3*). It depends generally on the number of ions and on their mobility. Under practical conditions different chemical contaminations may appear as the major sources of ions.

Dipole Orientation Polarization. Water and cellulose are both dipole dielectrics. The dielectric properties of the wet cellulose are very different from those of cellulose and water considered separately (*4*, *5*). Absorbed water does not have a dielectric constant of 80 and its dissipation factor is not 20 times larger than that of dry cellulose.

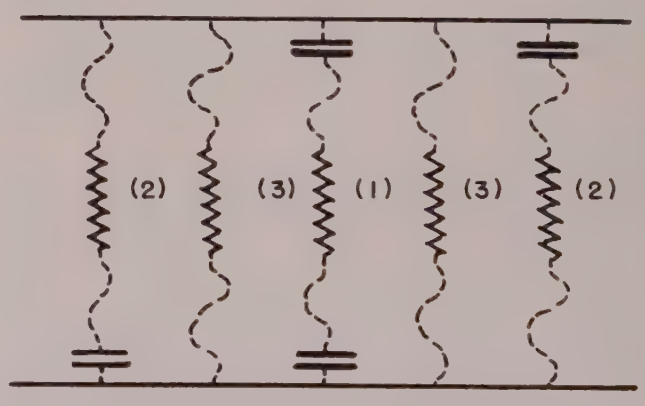

Fig. 1. Idealized picture of the interfacial polarization owing to conductance along the fibers

(1) Fibers having no contact with any electrode. (2) Fibers having contact with only one electrode. (3) Fibers having contact with both electrodes.

J. VITINS, present address: British Columbia Research Council, Vancouver 8, B. C., Canada.

* Moisture content is used here throughout to denote relative moisture content referred to the dry weight of sample.

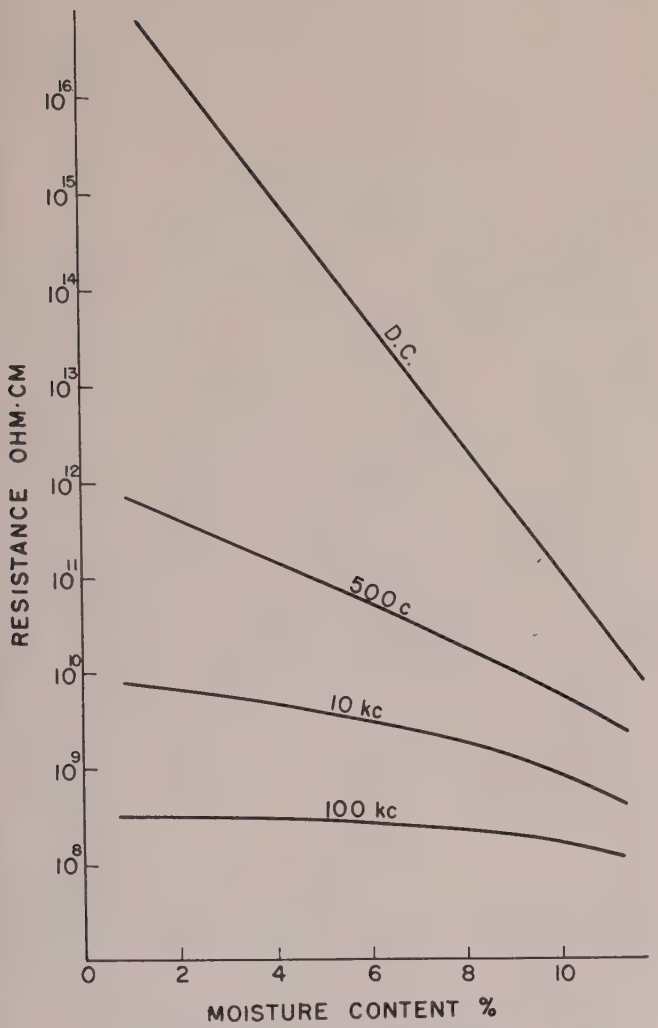

Fig. 2. Specific resistance of cable paper at room temperature

The region of dipole polarization is of more interest for moisture determination because here the properties of wet paper are directly dependent on the ratio of water to cellulose, but not on a third factor, a source of ions as in the case of interfacial polarization.

Atomic polarization. This is the effect of displacement of charged atoms or groups of atoms with respect to each other. It is well known that liquid water has two very strong absorption maxima; one due to the stretching vibrations, around 2.9 μ, and the other due to the bending vibrations of H-atoms, around 6.1 μ. The H-atoms of cellulose do not show bending vibrations and its absorption in the region of 6 μ is relatively low.

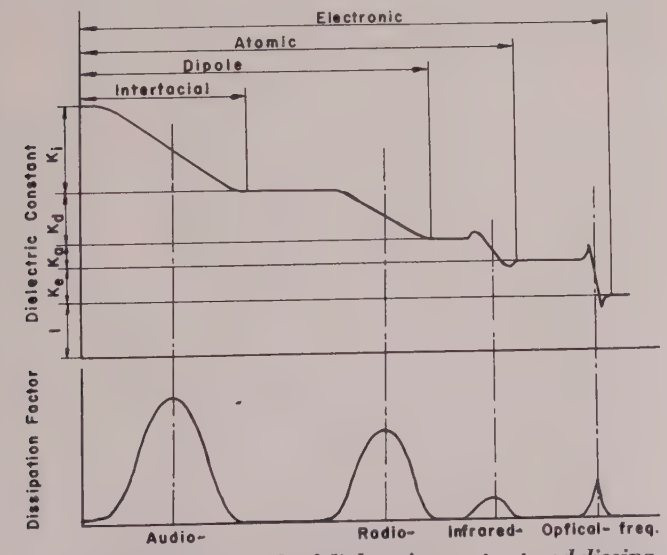

Fig. 3. Schematic graph of dielectric constant and dissipation factor variation with frequency. For interfacial polarization the equivalent mechanism of Fig. 1 is assumed

Figure 4 shows an approximate transmission spectra obtained by preliminary measurements for cellulose at different moisture contents. The scattering effect is not shown in this figure. Actually, because of the fibrous structure of cellulose, the main part of the incident radiation will neither be absorbed nor passed through the material but reflected in all directions, i.e., scattered. This process depends on a number of parameters. Unless a practical method is found for separating absorption measurements from scattering, the advantage of this region, where dielectric measurements are almost free of change-of-temperature effects, can hardly be utilized.

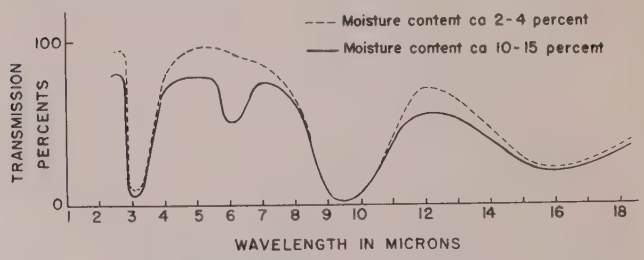

Fig. 4. Transmission spectra of cellulose at different moisture contents

Electronic Polarization. The polarization due to the displacement of electrons within the atom relative to its nucleus. Cellulose appears opaque in this region.

This short survey shows that at present only the regions of interfacial and dipole polarization are of interest for further consideration. The general relations for dielectric material described above have been used to construct Figs. 5, 6, and 7, which set out certain relationship for paper with different moisture content at room temperature. The figures have been constructed using measurements reported in references (*3*) through (*11*).

Figure 5 shows the dissipation factor, and Fig. 6 the dielectric constant as functions of frequency. It can be seen that the interfacial polarization gives an appreciable dissipation factor variation due to the moisture in the frequency region between 1 and 10^4 cycle per second, but dipole orientation between 10^8 and 10^{11} cycle per second. Figure 7 shows the dielectric constant at 10^6 cycle per second as a function of the moisture content.

The rate of variation of dielectric properties with temperature change is not constant but depends on the frequency and moisture content. This very important and undesirable dependence could not be obtained from the published data for the whole region of interest. Figures 8 and 9, based on measurements made at the British Columbia Research Council, demonstrate the temperature dependence of moisture determination on the basis of dissipation factor and on the basis of dielectric constant variation at a frequency of approximately 2.4×10^{10} cycle per second. In both cases to obtain the moisture content with an accuracy of 0.2% would require knowledge of the temperature of the sample to within 2°C.

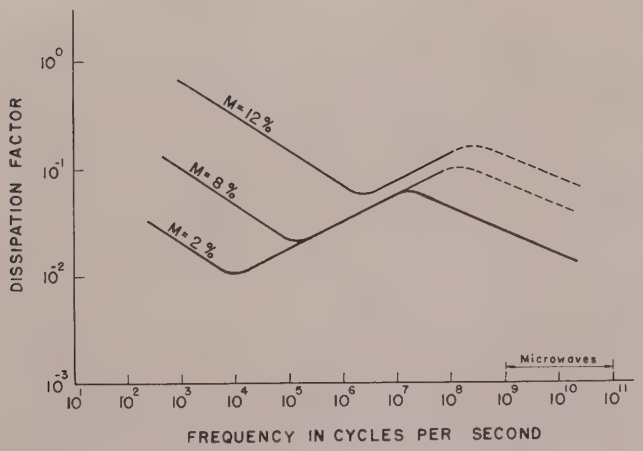

Fig. 5. Variation of dissipation factor with frequency at room temperature

The curves of Figs. 5, 6, and 7 present qualitative rather than quantitative values because the kind of cellulose, its treatment, and the composition of paper are not specified. The influence of these factors on d.c. resistance has been described by Hardacker and Rawcliffe (*1*), and the influence on the dissipation factor due to dipole orientation, by Nakanishi, Horii and Fujiwara (*11*). The fiber furnish is a major factor influencing the dielectric properties of paper. Compared with mechanical pulps, chemical pulps have approximately 200 times higher d.c. conductivity and double the dissipation factor at 10^{10} cycles per second. These maximum variations are equivalent to a change of moisture content of approximately 2.5%. At the frequencies between d.c. and 10^{10} cycles per second, the variation of the dissipation factor with fiber furnish is equivalent to appreciably larger changes of moisture content; see, for example, Figs. 16 and 17 of ref. (*1*).

The effect of common contaminations has been shown to be largely overshadowed by a certain spread of results which could not be explained always by inaccuracy of the equipment.

A hysteresis in moisture content variation with subsequent changes of air relative humidity is known, but the mechanism has had little investigation. There are some indications, possibly related to the hysteresis loop, that for the same moisture content the dielectric

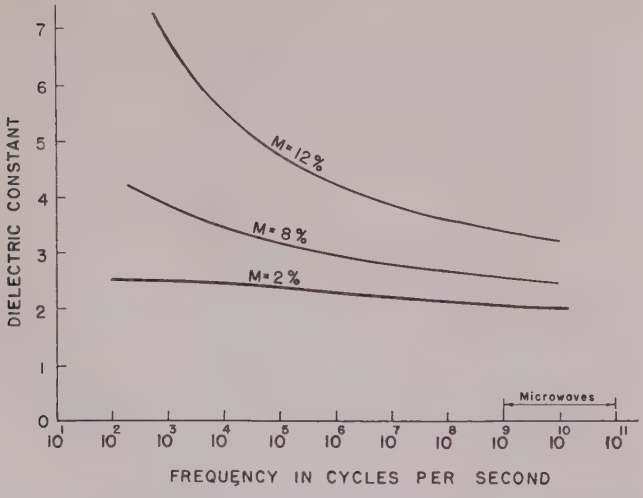

Fig. 6. Variation of dielectric constant with frequency at room temperature

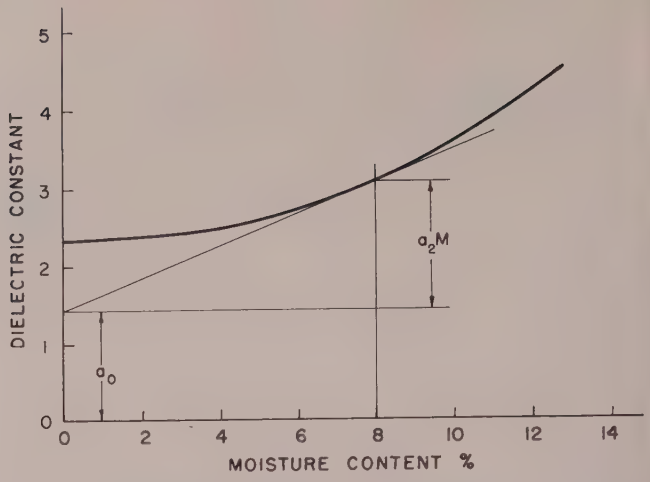

Fig. 7. Variation of dielectric constant with moisture content at 1 megacycle room temperature

properties are not necessarily constant. The insufficient knowledge of reasons for the resulting spread of single measurements seriously handicaps estimation of the accuracy of moisture determination which could be obtained by different methods.

NOTE: A recently received publication of Paavo Kajanne and Aarne Hollming "Hydrogen bonding as an uncertainty factor in continuous moisture determination of paper," *Paperi ja Puu* (Finland) 39, 465–470 (1957) illustrates the importance of investigations in this field.

ELECTRODE SYSTEM

The study above showed that measurements of the dissipation factor and dielectric constant may be utilized for moisture-content determination. The apparatus has to employ certain electrodes containing a fraction of the moving sample.

Generally, two directions of the applied field are possible: (1) across the sheet, and (2) along the sheet. Figures 10a to 10d show a few typical electrode arrangements. They have one common important characteristic: the sample does not fill up the whole space between the electrodes. These electrode systems permit measurement of capacitance change and dielectric losses, absorption or attenuation due to the sample; but the indicators of moisture content, dielectric constant and dissipation factor, can be calculated only if the basis weight is known. Because the fill factor is small, see Table I, the dependence on the basis weight

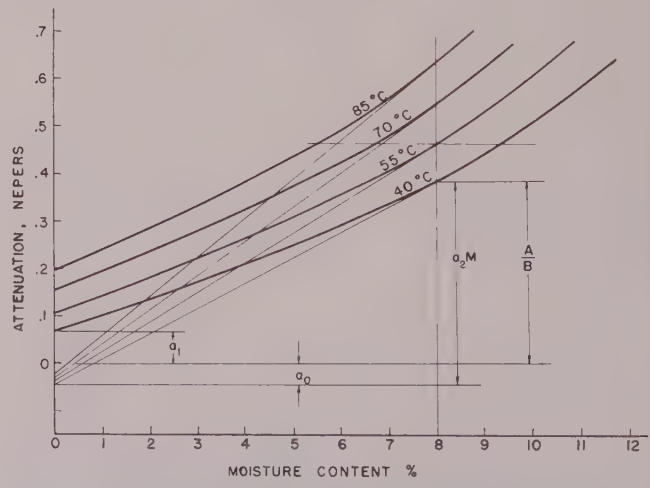

Fig. 8. Variation of attenuation at the frequency of 2.4 × 10^{10} cycles

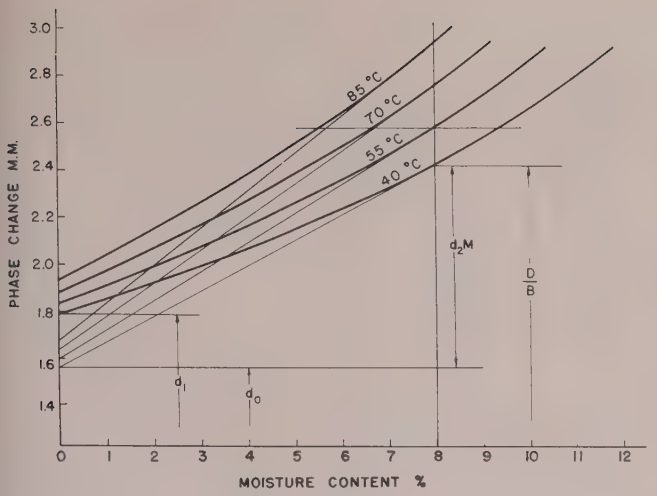

Fig. 9. Variation of phase at the frequency of 2.4 × 10^{10} cycles

is practically linear. The suitability of the different arrangements for a moisture meter was obtained from the calculation of capacitance and dielectric loss changes due to different factors. For this a sample of newsprint was used with:

Basis weight B = 35 lb (25 × 40 − 500).
Thickness d = 0.004 in. = 0.01 cm.
Dielectric constant K = 3 (Fig. 7).

Further, it was assumed that the required accuracy is 0.2% for moisture content and 2% for basis weight; that the temperature of the electrodes could vary between 30 and 70°C. and that the relative humidity

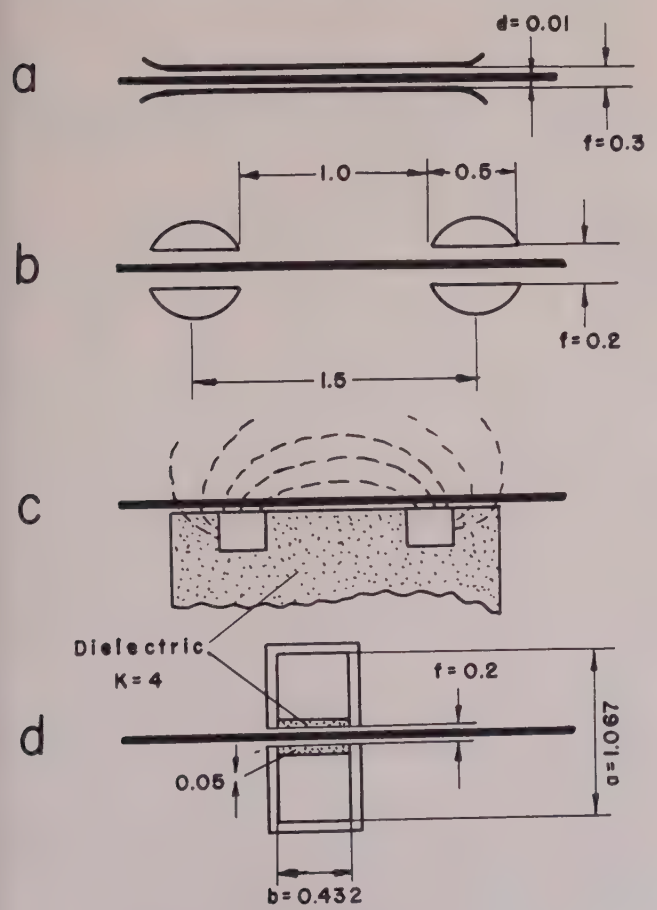

Fig. 10. Electrode arrangements. Dimensions in centimeters

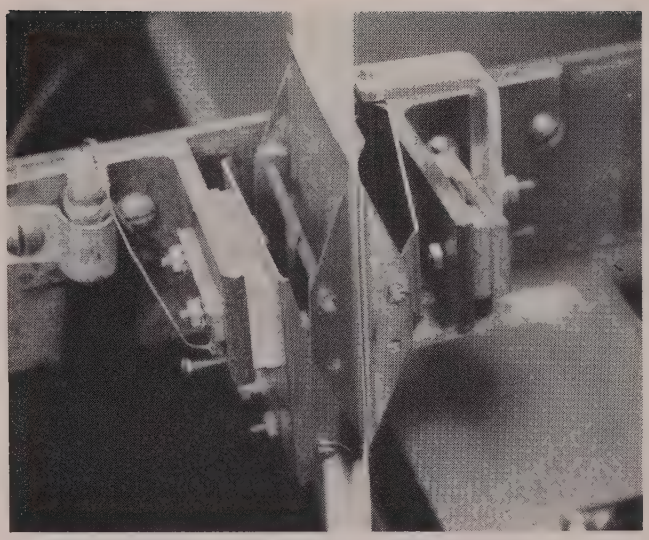

Fig. 11. Experimental gliding electrode arrangement

of the ambient air may be between 30 and 90 per cent.

Major sources of errors were considered to be: (1) variations of position of the sample relative to the electrodes, (2) changes of dielectric constant of air with relative humidity, (3) variations of the temperature of electrodes, (4) mechanical instability of the gap and of the position of the electrodes to each other.

With the electrodes of Figs. 10a, b, and d, the position of the sample coincides with the plane of symmetry of the electrodes. The errors due to the deviations from this position increase only gradually. With electrodes of Fig. 10c the relations are different: the capacitance would vary rapidly with the specimen movements perpendicular to its plane. The extent of the electrical contact between the electrodes and paper, particularly

Table I

Electrode figure	*Capacitance variation* × 10^{-2}	*Maximum variation* *Air R.H. at 55°C., %*	*Electrode temperature for expansion only, °C.*	*Gap* × 10^{-4} *in.*
10a	2.3	10	10	2
10b	1.1	5	5	3
10c	<0.4	≪ 5	1	[d]
10d[a]	3	15	3	10
10d[b]	2	35	2	7
10d[c]	0.3	1.5	0.3	10

[a] 10d, without dielectric walls.
[b] 10d, with dielectric walls.
[c] 10d, for 10-cm. wave guide, a = 7.22 cm., b = 3.40 cm.
[d] Considerable sensitivity to the small gap between paper and electrode surfaces.

at frequencies below 1 mc, considerably influences the apparent capacitance and dielectric absorption. Some preliminary experiments with metal gliding electrodes, Fig. 11, showed high sensitivity to the surface pressure, the speed of paper movement, smoothness of material and air humidity. The practical advantages of the electrode system of Fig. 10c are so considerable that this arrangement cannot be ignored.

The results of the calculations for a newsprint sample with six electrode systems and three sources of error are assembled in Table I. It presents the values of the different factors which would cause an 0.2% error in moisture determination on the basis of capacitance variation similar to that given in Fig. 7.

Table I shows that none of the electrode systems described can be used immediately for moisture determination by the capacitance method. These limita-

tions would, however, only slightly effect the moisture determination on the basis of measurements of the dielectric absorption.

With pulp and veneer the fill factors are higher and there are appreciably less difficulties in the design of an electrode system for the simultaneous measurement of capacitance or phase change and dielectric absorption.

An open microwave beam might be applied for moisture determination in solid wood. Temperature for such measurements is usually constant and known. The absorption and phase change measurements would replace capacitance and specific gravity measurements of one of the known best methods (*7*).

MEASUREMENT COMBINATIONS

The analysis of the properties of the material and electrode systems leads to the conclusion that for moisture determination it is most favorable to use attenuation measurements at 1×10^{10} to 2.5×10^{10} cycle per second. They must be complemented by basis weight and temperature measurements because otherwise a 10% change in basis weight would cause about 0.8% error and change in temperature of 10°C. would cause 0.7% error in moisture determination. This estimate is valid for newsprint with 8% moisture content.

An automatic control system comprising a moisture meter with basis weight and temperature corrections is described by Yasukawa (*12*). The methods used to determine these corrections were not published.*

Basis weight and temperature can be measured, e.g., be beta-ray gage and temperature gage, but they can at least partially be determined from measurements of dielectric properties of the sample. Further, the problem is approached from a more general point of view by a consideration of the possible combinations of the measurable variables; which could yield the three unknowns, moisture content, basis weight, and temperature in a more efficient way.

In the case of capacitance or dielectric absorption only the second can be utilized without the introduction of new undesirable variables. Basically it is possible to select three different frequencies such that in each of three simultaneous, separate absorption measurements the unknowns would enter at different rates. This would lead to three equations with three unknowns, from which the unknowns could be obtained by analog computers.

In the frequency regions of 10^3 to 10^4 and of 10^7 to about 10^{10} cycle per second the absorption increases approximately by a factor of 3 for the first 8% of moisture content. In two other regions it is almost independent of moisture content, one at 10^6 to 10^7 and the second over 10^{11} cycles per second, not shown in Fig. 5. Consequently four different frequency combinations are available for the simultaneous moisture content and basis weight determination by absorption measurements only.

The changes of temperature-dependence of absorption due to the variation of frequency has been too little investigated. With present knowledge it is impossible to estimate the accuracy to which the temperature of the sample can be determined from absorption measurements only. It is expected that such determination will not be sufficiently accurate.

The most efficient solution for the second measurement would be a capacitance or phase change measurement parallel to one of the absorption measurements. This requires a more elaborate electrode design. At present the development of a practical apparatus making measurements at the edge of the sheet with sufficient accuracy for automatic control of manufacturing appears possible.

As one example of a more elaborate electrode system, the following considerations illustrate the possibility of temperature and gap variation compensation for microwave electrodes (Fig. 10d). The equation for the wavelength in waveguide for the $TE_{1,0}$ mode is:

$$\lambda g = \frac{\lambda_0}{\sqrt{1 - \left(\frac{\lambda_0}{2a}\right)^2}}$$

where
λ_0 = wavelength in free space.
a = wide dimension of the guide, Fig. 10d.

Mechanical instability of supports causes variations of the width, a, at the same rate as the gap between the electrodes. The equation shows that two cavities can be designed, with different widths, a, and lengths, l, giving the same total variation of the phase due to the gap variation, but having different sensitivity to the sample.

The equal sensitivity of two cavities to temperature variations can be adjusted by the volume of dielectric insulation walls, Fig. 10d.

TABLE II

Temperature, °C.	Attenuation in nepers, (a_2 and A—at M = 8%)				Phase change in mm. (d_2 and D—at M = 8%)			
	a_0	a_1	a_2M	A/B	d_0	d_1	d_2M	D/B
40	−0.045	0.070	0.430	0.385	1.58	1.79	0.85	2.43
55	−0.035	0.111	0.503	0.468	1.62	1.84	0.98	2.60
70	−0.027	0.153	0.579	0.552	1.66	1.89	1.12	2.78
85	−0.020	0.195	0.655	0.635	1.70	1.94	1.26	2.96

Connection of two such cavities to opposite arms of a microwave bridge may produce cancellation of the errors due to variations of the gap and temperature of the electrodes.

EXPERIMENTS

A few experiments were carried out with audio frequencies and they confirmed the relations described above.

The major series of experiments was related to a study of the possibility of simultaneous determination of basis weight and moisture content in newsprint using the phase change and attenuation measurements of microwaves. A frequency of about 3×10^9 cycle per second appeared unfavorable for this purpose because of the relatively low fill factor, capacitance variation due to the sample being only 3×10^{-3}, Table I. The requirements for the gap stability, 10^{-4} in. with uncompensated electrodes, was too high for practical

* Recent correspondence showed that the system described appears to be the original solution using microwave absorption.

apparatus. No experiments were carried out on the degree of possible compensation of the gap variations.

Measurements of general interest and representing practically the only available quantitative information on the relations between the moisture content and temperature are presented by Figs. 8 and 9 and Table II. The table gives the values of the constants shown in the figures. The sample was a newsprint sheet 7-in. wide, with dry weight $B = 36$ lb. $(25 \times 40 - 500)$, the frequency is 2.4×10^{10} cycles per second, A and D correspond to the moisture content $M = 8\%$.

All these measurements showed a higher spread of single measurements from the average value than would be expected on the basis of inaccuracy of the equipment. This spread increased with moisture content. A similar spread was also found in the measurements published by different investigators (*1, 11.*)

SUMMARY

All known marketed apparatus (*2, 13–15*) was initially designed for moisture determination on the basis of a single measurement of one of the dielectric properties of the sample. The considerations presented show that under practical conditions at least three different simultaneous measurements are necessary for automatic moisture control because any single measurement depends upon the basis weight and temperature of the sample. Two of the three measurements needed can be absorption measurements at two different frequencies. One could be a capacitance measurement if the influence of the gap and electrode temperature is sufficiently compensated.

A few versions of the apparatus designed on the basis of the described principles are disclosed in one pending patent, but it is felt that the study of dielectric properties of paper at high frequencies should be continued. More experimental information on the frequency spectrum of dielectric properties at different temperatures and moisture contents would considerably accelerate the development of practical instrumentation for moisture determination.

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Effects of a Decay Producing Organism, *Peniophora gigantea* (Fr.) Massee, on Quality of Pulp from Jack Pine*

W. McNEEL, JR., R. D. SHENEFELT, T. A. PASCOE, and T. C. SCHEFFER

A study designed to measure losses by insects attacking jack pine pulpwood in Central Wisconsin was initiated by the Nekoosa Edwards Paper Co. Direct measurements of wood losses caused by insect activity were obtained, but it was extremely difficult to measure their influence on pulp quality. It was found, however, that the amount of wood decay, caused almost entirely by the wood rotting organism *Peniophora gigantea* (Fr.) Massee, and the amount of blue stain was considerably less in pulpwood where insects were controlled. This association between insect abundance and amounts of *P. gigantea* led the investigators to determine the effect of this wood rotter on pulp quality. Increases in the percentage of decay in pulpwood caused significant decreases in burst, tear, tensile strength, caliper, opacity, and probably folding endurance of pulp. A slight increase in pulp yields during storage was very probably due to the type action of *P. gigantea* on wood components. Pulpwood, and consequently pulp, is variously affected during storage depending on the conditions that favor or retard fungus growth. A measurement of decay is a far better estimate of the quality of pulp than other criteria such as length of storage. By determining the amount of decay in jack pine logs, it is possible to estimate the value of the pulp obtained.

W. McNeel, Jr., Assistant Professor, Central Michigan University; formerly Research Associate, Department of Entomology, University of Wisconsin. R. D. Shenefelt, Professor, University of Wisconsin; T. A. Pascoe, Manager, Research Department, Nekoosa Edwards Paper Co.; T. C. Scheffer, Pathologist, U. S. Forest Products Laboratory.

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During a study designed to determine the influence of insects in stored jack pine pulpwood, it became apparent that there was a definite association between

insect infestation and abundance of blue stain and wood rotting organisms (McNeel, et al. (*1*)). Fungus development was retarded for at least 9 months by preventing the insects from entering. Although direct wood losses due to insects can be determined (McNeel, (*2*), unpublished Ph.D. thesis), it is extremely difficult to measure their direct influence on pulp quality. However, the amounts of decay are correlated with insect activity, and the effects of decay on pulp yields and pulp quality are determinable. Results of this phase only of the investigation are reported herein.

The fungi which prevailed were almost exclusively blue staining species of the genus *Ceratostomella* and the wood rotter, *Peniophora gigantea* (Fr.) Massee. *P. gigantea* seems to be the most prevalent decay producing fungus in green pine wood in both the North and South and probably accounts for most of the early pulpwood decay in the southern and Lake States regions. Pulpwood deterioration studies on northern tree species by Pascoe and Scheffer (*3*), and McNeel, et al. (*1*), and on southern pines by Lindgren (*4, 5*), and McGovern, et al. (*6*), all were concerned with this organism. This fungus, like other decay organisms, attacks the tracheids which are the important structural elements of softwoods. As a consequence of infection, therefore, the wood sustains losses in both weight and strength.

Blue stain fungi appear to be of much less consequence to the paper industry than decay producing organisms. According to Curran and Behre (*7*), Chidester, et al. (*8*), Chapman and Scheffer (*9*), Cart-

Table I. Average Percentages Superficial and Volume Blue Stain and Decay and Wood Densities of Sprayed and Untreated Wood Cut at Monthly Intervals After Different Storage Intervals

Months of storage	Superficial blue stain %			Volume bule stain, %			Superficial decay, %			Volume decay, %			Densities	
	Untrtd.[a]	Trtd.[b]	Diff. %	Untrtd.	Trtd.	Diff. %	Untrtd.	Trtd.	Diff. %	Untrtd.	Trtd.	Diff. %	Untrtd.	Trtd.
Cut in April														
3	23.5	10.3	56.2	40.1	16.9	57.8	0.1	0.1	0	0.4	0.1	97.5	24.1	24.2
6	60.4	57.5	4.8	39.3	27.4	30.2	13.0	0.4	96.7	22.6	2.2	90.2	24.2	23.7
9	46.5	37.5	19.4	30.0	19.0	36.6	29.2	5.4	81.5	21.0	10.0	52.3	25.2	24.4
16	16.0	20.7	−22.7	18.3	14.4	21.3	82.5	70.7	14.3	69.2	62.8	9.2	24.1	24.1
26	12.5	12.5	0	22.2	5.0	77.4	77.5	77.3	0	49.5	65.8	24.7	24.4	24.2
Cut in May														
3	36.5	26.0	28.7	36.4	17.0	53.3	2.5	0.34	86.4	1.6	1.1	31.3	24.8	25.3
6	39.5	61.9	−35.7	32.7	35.8	−8.7	38.9	12.4	68.1	24.2	17.5	79.2	24.3	24.8
9	31.9	46.5	−31.3	39.0	17.7	54.6	68.0	7.6	88.8	43.6	15.4	64.6	25.4	25.1
15	9.5	17.4	−45.4	11.4	32.2	−64.5	90.5	83.4	78.4	87.5	64.5	26.2	24.3	23.0
26	22.2	15.5	30.2	20.0	15.8	21.0	73.8	83.8	−11.9	74.6	66.2	11.3	23.9	23.0
Cut in June														
1	1.3	0.3	73.1	0	2.5	−100	0.1	0.1	0	0.1	0.1	..	23.9	24.2
2	42.0	21.8	48.0	22.0	7.2	67.2	0.1	0.1	0	0.9	0.2	77.7	24.4	24.8
3	51.0	55.2	−7.6	36.4	23.2	36.2	28.0	8.4	69.8	9.0	4.8	50.0	24.1	24.2
4	36.5	54.0	−32.4	26.8	27.8	−3.6	57.5	9.0	84.3	56.5	2.6	95.3	24.0	24.3
5	25.0	54.0	−53.7	18.4	21.0	−12.4	72.8	6.8	90.6	66.8	14.3	78.5	23.9	24.1
6	39.8	66.3	−39.9	27.0	39.6	−31.8	59.0	0.6	99.0	56.0	5.1	90.8	24.2	24.1
7	29.3	52.0	−43.6	20.0	28.0	−40.0	60.5	16.6	72.5	76.0	8.0	89.4	25.4	24.3
8	29.9	60.4	−50.4	23.6	18.4	−32.0	66.9	6.0	91.0	60.6	2.6	95.7	24.1	24.9
9	36.2	46.3	−21.8	20.0	26.4	−32.0	61.3	10.8	82.4	69.8	9.0	87.1	24.8	23.8
25	3.0	11.0	−72.7	3.8	16.1	−76.3	97.0	89.0	8.2	91.5	82.5	9.8	23.4	22.3
Cut in July														
3	78.3	48.8	38.6	56.5	29.0	48.6	22.0	6.9	68.6	6.0	3.6	40.0	24.2	24.1
6	50.0	49.8	0.4	43.0	37.0	13.9	33.2	20.7	37.6	17.0	10.0	44.2	24.2	24.7
9	42.0	30.5	27.3	47.8	22.7	52.5	52.0	7.9	84.9	22.2	5.6	74.7	23.4	24.7
13	9.6	12.3	−21.9	16.6	9.5	42.7	83.6	82.8	0.9	50.8	65.8	−22.7	24.9	23.5
24	51.7	7.4	−22.9	7.6	4.7	38.1	91.0	87.0	4.4	71.0	71.7	−0.9	22.2	23.3
Cut in August														
3	63.5	28.1	55.7	34.8	5.8	83.3	1.5	0	100	0.4	0.8	−50.0	23.8	23.4
6	50.3	29.2	41.9	20.6	9.9	51.9	3.1	1.7	45.1	0.1	0.1	..	26.6	25.4
9	44.3	27.0	39.0	24.2	5.0	79.3	21.9	7.7	64.7	0.3	1.0	−33.3	24.6	24.8
13	21.5	27.0	−20.4	17.4	18.8	−7.4	72.2	32.3	55.3	49.8	35.4	28.9	23.5	24.0
23	8.7	14.7	−40.8	15.2	8.8	42.1	80.7	67.9	15.8	80.9	49.1	38.4	22.7	24.0
Cut in September														
3	0	0	..	0	0	..	0.1	0.1	..	0.1	0.1	..	24.1	25.9
6	0.4	0.1	75.0	0	0	0	0.1	0.1	..	0.1	0.1	..	24.9	24.5
9	22.2	6.2	72.0	27.2	18.2	33.0	0.7	0	100	7.6	7.6	0	25.3	24.9
12	27.0	18.1	33.0	38.8	4.5	88.4	65.8	10.0	84.8	21.8	23.4	−6.8	24.6	24.3
22	10.5	5.5	47.6	5.2	2.9	44.2	89.0	71.1	20.1	93.8	66.5	29.1	22.1	23.5
Cut in October														
3	0	0	..	0	0	..	0	0	..	0	0	..	25.5	25.3
6	0.3	0.2	22.2	0.5	0	100	0	0.2	−100	0	0	..	24.7	24.4
9	61.5	10.0	83.7	4.9	8.3	−40.9	17.3	1.3	92.7	12.3	5.9	52.0	24.4	25.0
11	16.8	17.2	−2.3	17.2	39.3	−56.2	64.2	19.1	67.0	25.5	15.2	40.3	24.6	25.0
21	7.7	7.7	0	5.6	8.0	−30.0	81.8	81.8	0	76.1	65.2	14.3	23.1	23.2

[a] Untreated.
[b] Treated.

Fig. 1. Jack pine pulpwood logs being examined for insects and fungi at the Nekoosa storage yard

wright and Findlay (*10, 11*), neither wood nor pulp suffers objectionable losses in strength from stain. The authors of the latter three works report that only toughness is appreciably affected by stains. The generally mild effect of blue stain fungi on strength is attributable to the fact that these organisms feed on starches, sugars and other soluble or semisoluble materials contained in the wood cells, and sparingly, if ever, attack the tracheids (Kress, et al. (*12*)), (Scheffer and Lindgren, (*13*)). Although quantitatively measured in this study, blue stain appeared to be of little concern and its influence on pulp quality was not analyzed.

PROCEDURES

In the Cutting Area. Jack pine, *Pinus banksiana* Lamb., was selected for study as it composed the bulk of the softwood pulped by the Nekoosa Edwards Paper Co. The wood was taken from a stand of trees approximately 40 years old with an average d.b.h. of about 7 in. One hundred logs, roughly two cords, were cut each month from April through October. One cord served as check material; the other was sprayed with benzene hexachloride emulsion immediately after cutting. Following spraying, the logs lay in the usual decks in the woods for a month and were then hauled to the storage yard and placed on skids. Extra logs were piled over the test logs to stimulate natural yard conditions.

Fig. 2. Heavy surface growth of P. gigantea mycelium in bark beetle galleries

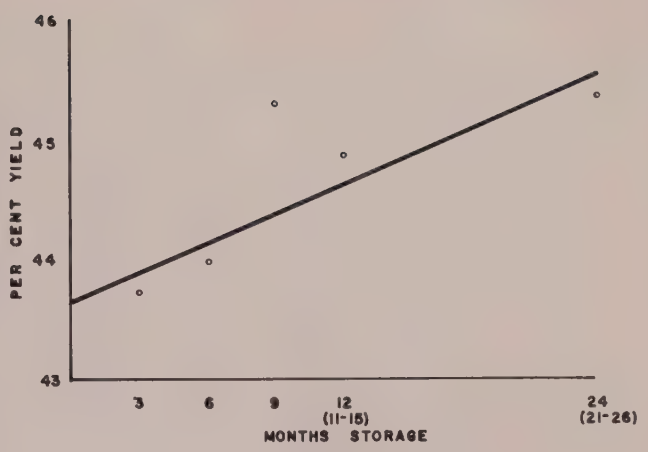

Fig. 3. Per cent yield after storage

In the Storage Yard. Ten logs from each cord were examined at each of five different periods to determine the status of insect populations and injury and that of the fungi. The first three examinations were made after 3, 6, and 9 months' storage, but the intervals for the last two examinations varied somewhat. The maximum period of wood storage was 26 months for wood cut in April and the minimum 21 months for wood cut in October. A total of 1170 logs were examined (Fig. 1). Because of the detailed examination and recording necessary to follow the events which were occurring it was impossible to work with a larger number of logs.

The amounts of blue stain and decay were recorded in two ways: (1) as per cent of log surface covered by stain or *Peniophora* mycelium (Fig. 2), and (2) as per cent of volume affected. To determine the latter, two 1-in. disks were cut from each log, one from the center and the other 16 in. from the butt end. The volumes affected were considered to be equivalent to the percentages of total area affected on the faces of the disks. Inconsistencies were kept to a minimum by having only one appraiser. A close correlation was found between estimations of per cent surface affected and volume of decay. However, volume estimates were employed as they seemingly provided a truer estimate of the total wood decayed. The average percentages of superficial and volume estimates of both

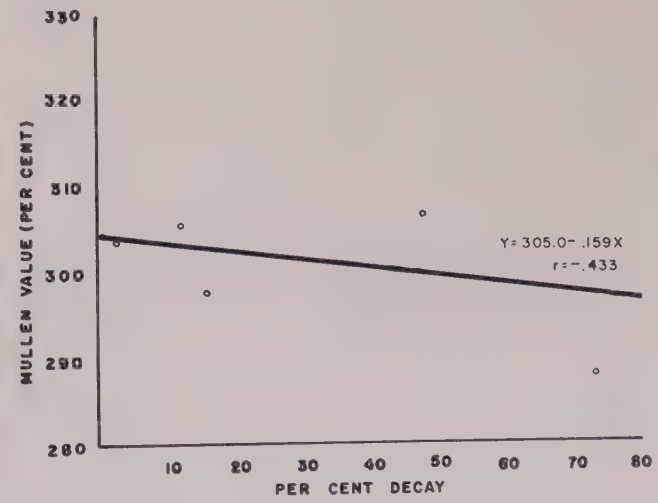

Fig. 4. Regression of per cent decay and Mullen value

Table II. Results of Pulp Tests Made on Treated and Untreated

Month cut	Months of storage	Yield, %		Burst		Tear[c]		Pulp values		Tensile strength	
		Untrtd[a]	Trtd.[b]	Untrtd.	Trtd.	Untrtd.	Trtd.	Untrtd.	Trtd.	Untrtd.	Trtd.
April	3	43.5	44.1	289	298	306	294	595	592	74.1	80.1
	6	43.9	43.6	300	306	287	294	587	600	82.5	82.1
	9	44.0	43.5	306	274	256	242	562	516	78.9	79.5
	11–16	44.1	43.9	294	296	236	265	530	561	76.3	79.0
	21–26	46.4	42.1	291	295	244	271	535	566	83.0	74.9
May	3	44.2	45.4	291	283	333	372	624	655	71.0	78.4
	6	44.1	41.5	308	309	278	313	586	622	78.2	80.6
	9	44.2	45.1	285	292	260	270	545	562	82.6	79.5
	11–16	45.1	46.5	296	305	253	242	549	547	71.9	81.4
	21–26	46.7	43.6	296	288	283	267	579	555	74.9	74.7
June	3	42.8	43.1	299	301	335	313	634	614	78.2	81.3
	6	44.1	44.9	283	328	356	334	639	662	75.1	80.1
	9	44.2	43.6	278	302	282	325	560	627	81.8	80.8
	21–26	46.7	44.8	278	290	289	277	567	567	74.1	71.0
July	3	44.5	45.5	291	297	322	317	613	614	83.3	81.8
	6	43.4	44.4	299	324	286	305	585	629	80.6	87.5
	9	42.1	45.3	297	282	315	325	612	607	82.8	80.0
	11–16	44.8	44.1	315	326	277	240	592	566	83.4	81.4
	21–26	46.4	47.7	298	291	270	278	568	569	74.2	73.6
Aug.	3	40.8	44.2	301	332	317	356	618	688	76.8	79.5
	6	45.6	44.6	314	302	284	309	598	611	85.1	82.9
	9	45.8	46.8	293	306	308	293	601	599	79.6	82.7
	11–16	43.8	46.1	305	321	298	266	603	587	74.8	81.6
	21–26	43.0	45.6	280	293	245	307	525	600	72.1	70.4
Sept.	3	43.1	44.6	329	311	336	370	665	681	83.9	74.6
	6	42.8	44.1	314	291	308	287	622	578	86.3	76.9
	9	47.2	44.3	316	307	344	342	660	649	81.5	79.0
	11–16	46.1	44.3	312	327	301	315	613	642	78.7	78.9
	21–26	45.4	45.2	278	292	269	244	547	536	68.5	71.6
Oct.	3	43.8	45.3	309	306	298	298	607	604	82.2	87.1
	6	41.3	46.7	299	310	341	351	640	661	80.4	84.3
	9	47.1	47.4	300	302	379	376	679	678	78.4	75.4
	11–16	44.3	44.0	298	313	290	291	588	604	74.4	78.7
	21–26	45.2	45.2	277	293	239	310	516	603	72.5	72.3

[a] Untreated.
[b] Treated
[c] Figures given are sums of 30- and 50-minute beating intervals.

decay and blue stain as well as densities of the test wood are included in Table I.

Both Pascoe and Scheffer (*3*), and Lindgren (*4*) measured decay by another criterion called the decay index, which takes into consideration the stage of decay as well as the volume of wood affected. This index was not employed, however, because of the observations by Lindgren that when the decay is caused largely by *Peniophora gigantea* and does not exceed 80 to 90%, an estimate only of the volume affected is a satisfactory measure of the magnitude of the decay.

At the Mill. After examinations were completed and disks removed, the log sections were hauled to the mill and run separately through a chipper. The chips were thoroughly mixed and a sufficient quantity for test cooks were screened. Chips were then taken from a mixture of the screenings and cooked. Duplicate and often triplicate kraft cooks consisting of 3000 g. of moisture-free wood, were made for each lot of wood. Results are included in Table II.

The cooks were made with 1 g. of ovendry chips to 3.8 ml. of total liquid. The chemical consisted of 600 g. (20% of weight of ovendry chips) of active alkali in the form of NaOH and Na_2S (expressed as Na_2O), with the Na_2O forming 30% of the total alkali solution. The chips were cooked in a small digester for 4 hr. and the temperature was raised at designated time intervals, the schedule following that used under mill conditions.

Room temperature to 100°C.	15 min.
100 to 125°C.	30 min.
125 to 170°C.	2½ hr.
170°C.	1 hr

After cooking, the pulp was washed and screened. The per cent yield was calculated by dividing the ovendry weight of the pulp by the ovendry weight of the chips cooked. As a measure of the reactions of the various wood samples to a standard cooking procedure, permanganate numbers were determined for each pulp using TAPPI Standard T 214 m-50. Physical qualities of the pulps were determined using essentially TAPPI Standard T 200 m-45, T 205 m-53, and T 220 m-53. The figures used for comparison were obtained by adding the burst and tear results for the 30 and 50-min. beating intervals. These figures were in turn averaged for the duplicate cooks. A single pulp quality index was used in some of the comparisons. This was obtained by adding the values above referred to for the bursting strength to the values obtained for the tear strength. This index was termed the "pulp value."

RESULTS

Correlations between decay and pulp quality criteria are given in graphic form. These should be useful in estimating pulp quality from jack pine logs. A review of the literature reveals many articles dealing with changes in pulp quality during storage. However, length of storage and conditions in the cutting areas and yards are often unknown. Regardless of the past history of the wood, the per cent infection by decay can be estimated. Decay, not length of storage, is the criterion affecting pulp quality. It is evident that old wood stored under ideal conditions may have less decay and give pulp of better quality than comparatively fresh wood cut and stored under situations favorable for rapid development of decay. These

Caliper		Pulp density		Opacity		Stretch		Folding endurance		$KMnO_4$ no.	
Untrtd.	Trtd.	Untrtd.	Trtd.	Untrtd.	Trtd.	Untrtd.	Trtd.	Untrtd.	Trtd.	Untrtd.	Trtd.
6.6	6.7	28.0	27.8	181	182	7.7	..	2571	2958	22.4	22.4
6.7	6.5	27.7	28.7	183	181	..	..	2861	3397	21.5	20.2
6.5	6.6	27.8	28.0	181	181	..	6.4	3927	2261	21.8	21.8
6.1	6.2	29.5	29.6	176	174	6.7	6.4	..	..	24.3	24.5
6.2	5.9	29.7	31.1	174	166	6.3	6.9	4050	4319	26.2	26.9
7.5	7.7	24.3	24.7	185	185	..	..	3060	3290	21.0	21.7
6.2	6.4	29.7	28.3	176	180	..	..	2577	2744	20.7	21.1
6.5	6.4	28.3	28.2	184	178	5.4	5.4	1879	2714	20.8	19.7
6.0	6.5	29.6	28.4	176	179	5.4	6.1	..	..	25.3	26.3
6.0	6.0	31.1	30.9	175	172	7.2	6.7	4445	4572	27.3	28.1
6.8	6.5	26.9	28.1	179	181	..	..	3479	3503	18.8	19.0
6.8	6.7	27.6	27.2	180	177	..	..	3066	2337	21.6	20.9
6.5	6.8	28.3	27.5	183	182	5.6	6.4	2029	2162	20.3	22.4
6.1	5.9	30.0	31.0	168	167	6.7	7.2	4734	5000	26.5	26.2
6.6	6.5	27.3	28.2	182	179	..	..	2984	3471	21.5	22.4
6.7	6.6	27.3	28.1	180	182	6.2	6.4	1683	1743	19.3	19.9
6.6	7.0	27.5	26.8	176	180	7.4	6.8	2479	..	21.4	21.0
6.4	6.2	28.9	29.2	175	173	6.1	5.8	..	..	22.9	24.8
6.1	6.0	30.3	30.3	173	166	6.7	6.2	4752	4775	27.2	24.3
6.4	6.8	29.1	27.5	177	181	..	..	3702	2872	18.9	19.8
6.4	6.5	27.9	27.7	177	181	5.5	7.1	2195	1789	20.1	18.3
6.3	6.3	29.3	29.5	178	167	6.4	6.9	2907	3315	22.9	23.2
6.2	6.1	29.4	30.0	168	167	6.2	6.6	1803	2432	22.5	22.3
5.9	6.1	31.1	29.7	169	169	5.8	6.8	4239	4567	25.4	23.4
6.3	6.6	28.9	27.9	176	175	..	..	3803	3824	19.8	20.0
6.3	6.6	29.0	27.9	172	182	5.9	5.8	2333	3252	17.1	21.1
6.7	6.4	28.7	29.3	177	172	6.1	6.4	..	..	24.9	25.3
6.3	6.1	29.2	29.5	169	165	7.6	6.6	..	..	22.6	22.7
5.8	5.8	31.9	31.2	164	163	5.6	6.1	3988	4469	22.8	25.9
6.7	6.9	27.4	26.7	175	180	6.0	6.2	2802	2789	19.2	19.9
6.9	6.5	27.1	27.9	174	170	6.7	6.7	2114	2299	20.7	21.3
6.9	6.5	27.4	28.7	177	170	7.3	6.5	..	..	25.6	26.6
6.2	6.1	29.3	29.4	171	171	6.2	5.7	..	..	23.7	23.2
5.7	6.2	33.2	29.4	165	170	6.9	6.6	4733	4333	24.4	26.1

graphs, then, offer convenient criteria for estimating pulp quality from any batch of jack pine logs.

Analyses of variance by Snedecor, (*14*) were made on all pulp data in Table II to determine if significant changes in pulp quality occurred during storage or were affected by season of cutting or treatment. The analyses showed that season of cutting had no significant influence on wood stored for storage periods up to approximately 2 years, the length of this study.

Pulp Yields

Pulp yields were significantly changed during storage ($F=4.26$; L.S.D. $5\%=3.16$). As it was found that no significant difference existed in yields between treated and untreated wood, all test wood was combined and the averages at the different storage intervals are shown in Fig. 3.

Slight increases in yields occur with increase in decay (although not of sufficient magnitude to be detectable by a test of correlation significance) indicating that there might be a weak but somewhat selective action on lignin by the organism.

Similar increases in yield during storage were observed by Rue, Miller, and Humphrey (*15*), Schwalbe (*16*), and Riley (*17*), all of whom found that yields of pulp cooked on a weight basis increased after wood storage and infection by certain fungi. The slight increase detectable in this study may be due to the

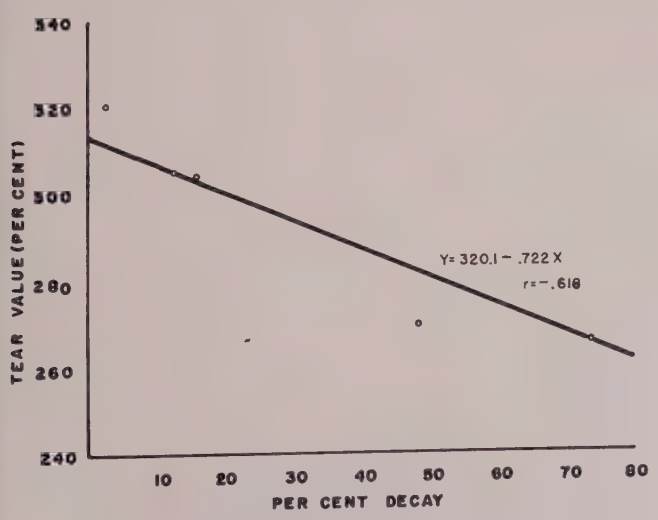

Fig. 5. Regression of per cent decay and tear value

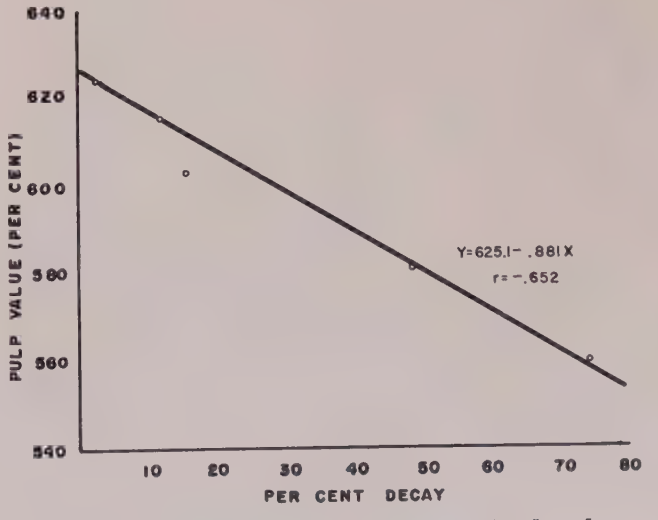

Fig. 6. Regression of per cent decay and pulp value

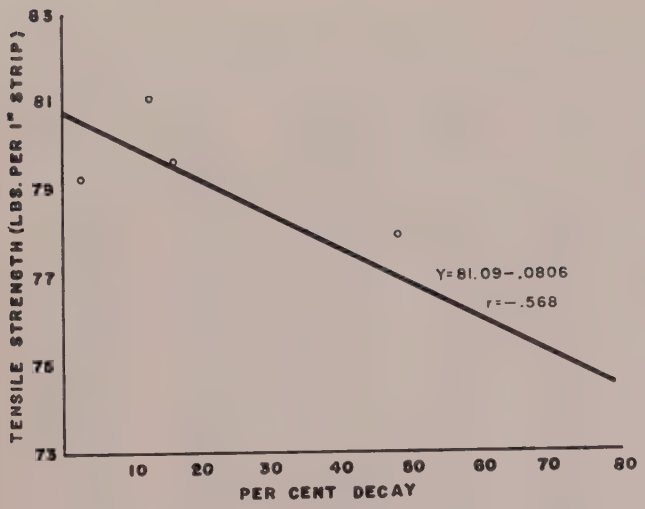

Fig. 7. Regression of per cent decay and tensile strength

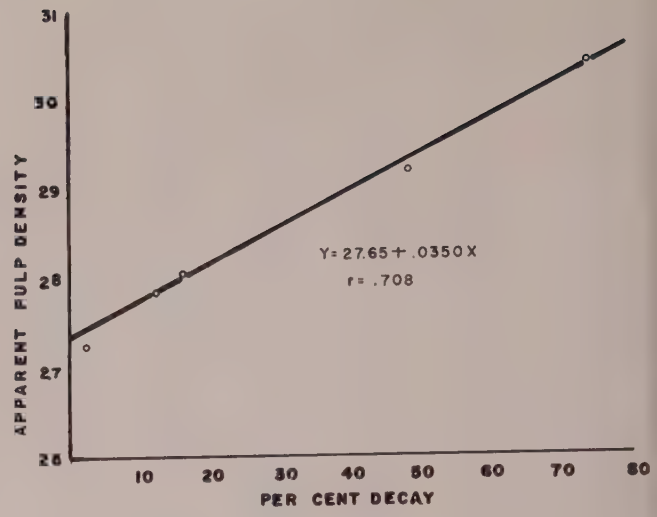

Fig. 9. Regression of per cent decay and pulp density

action of *P. gigantea*, which Davidson et al. (*18*), found to react in the oxidase test as a weak white rotter. McGovern, et al. (*6*), and Lindgren (*5*) report this organism to be intermediate in its action on wood between white and brown rotters. It attacks the cellulose and lignin more or less proportionately, thus causing no large change in relative amounts of these wood constituents. However, since the digesters are filled on a volume basis the effect of loss of wood density is one of loss of actual yield per unit of volume.

Tests for Pulp Quality

Analysis of variance of the data in Table II indicated that burst is significantly decreased as decay increases (F=6.35; L.S.D. 5%=3.16). Tests for common regression between the treated and the untreated wood showed that no significant differences in the two regressions existed (F=1.01; L.S.D. 5%=3.99). The correlation between decay and mullen values for all wood was significant, and the common regression at the separate storage intervals is plotted in Fig. 4.

Tear values were much more sensitive to the influence of decay than burst. These values changed significantly as the decay increased (F=18.78; L.S.D. 5%=3.16). No significant differences between the regressions of treated and untreated wood existed (F=0.469; L.S.D. 5%=3.99). The correlation between decay and tear values for all wood was significant, and the common regression plotted (Fig. 5).

The significant decrease in pulp value obtained was expected, as both burst and tear values showed significant decreases. Tests for the common regression showed that there were no significant differences between the regressions of treated and untreated wood, and a common regression was plotted (Fig. 6) to show the relationship between pulp value and volume of decayed wood.

Tensile strength was significantly reduced as percentage of decay increased (F=18.40; L.S.D. 5%=3.16). There was no significant difference between the regressions of treated and untreated wood (F=0.222; L.S.D. 5%=3.99). The correlation between tensile strength and decay was significant, and the common regression is shown in Fig. 7.

For some reason caliper was significantly reduced as decay increased (F=39.48; L.S.D. 5%=3.16). No significant differences existed between the regressions of the treated and untreated wood (F=0.149; L.S.D. 5%=3.99). The difference in caliper at different

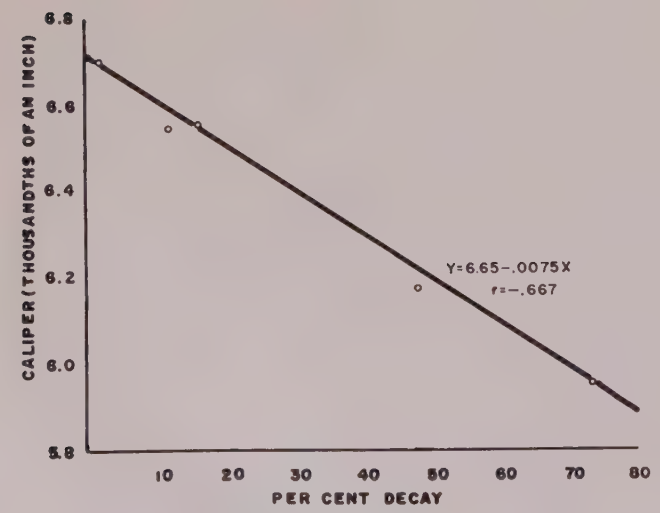

Fig. 8. Regression of per cent decay and caliper

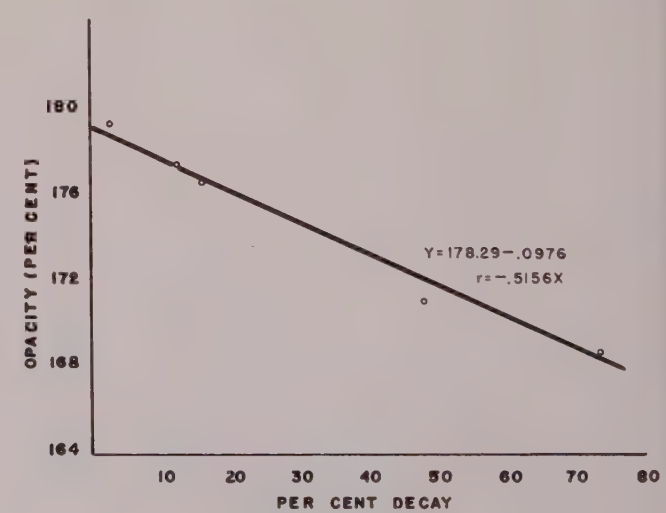

Fig. 10. Regression of per cent decay and opacity

storage periods for all wood was significant and a common regression calculated and plotted (Fig. 8).

Apparent density increased with the amount of decay ($F = 43.94$; L.S.D. $5\% = 3.16$), significant increases occurring after 9 months of storage. No significant differences existed between the regressions of treated and untreated wood ($F = 0.840$; L.S.D. $5\% = 3.99$).

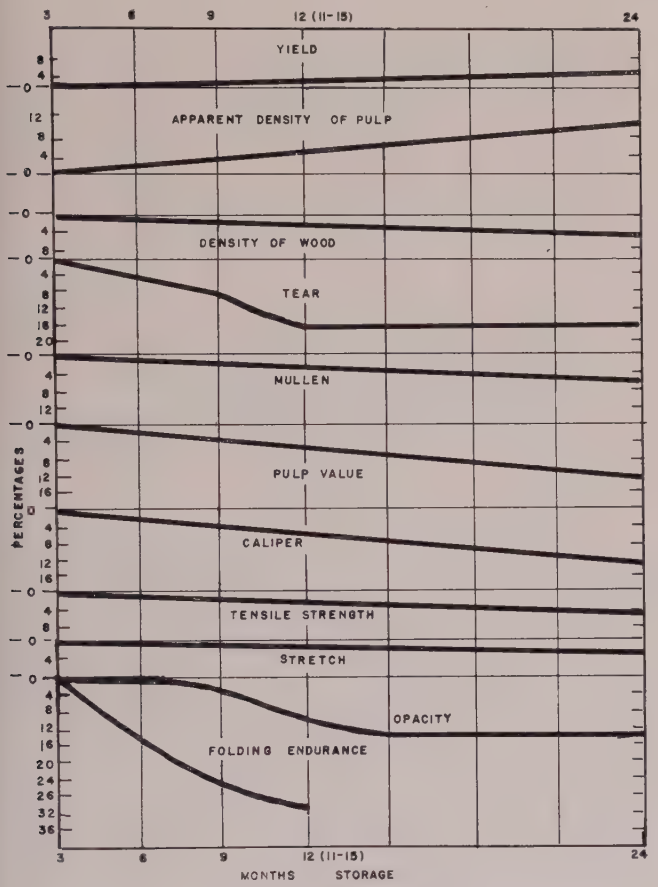

Fig. 11. Per cent changes in pulp test criteria during storage

The correlation between apparent density and decay was significant and a common regression was calculated and plotted (Fig. 9).

Opacity was significantly reduced by decay. It was the only pulp quality which proved to be affected by season of cutting. No significant difference in the regressions of treated and untreated wood existed ($F = 2.83$; L.S.D. $5\% = 3.99$). The correlation coefficient was significant, and the common regression was determined and plotted in Fig. 10.

As Table II indicates, only scattered tests were made to determine the effects of decay on stretch and folding endurance. These data were too sparse and variable to analyze statistically. No definite indication was apparent of how stretch was affected. Folding endurance was reduced 35% between the 3 and 11 to 15-month storage interval, but after 21 to 26 months storage was 28% higher than the initial value obtained at 3 months. Martin (*19*) reported a 40% decrease in folding endurance after 26 months' storage of jack pine in northern Minnesota. The changes observed during storage for these criteria and all others mentioned are given in Fig. 11 in percentages.

Decay results in a serious loss in pulp quality. The more sensitive properties: tear, caliper, opacity, and in all probability folding endurance, are easily determined and show the reduction in value (Fig. 11). Paper which must meet high requirements in these features should be made from as fresh wood as possible. Burst, tensile, and stretch values appear to be affected least adversely during storage.

SUMMARY

Peniophora gigantea was found to be the only important wood rotting fungus in the jack pine logs used in these tests. This organism is one of the most potent decay-producing fungi in pine and is one of the commonest rotters found in coniferous logs in the south and Lake States regions.

Wood, and consequently pulp, is variously affected during storage depending on conditions that favor or retard fungus growth. The effect of decay on various pulp qualities is shown. By determining amounts of decay in jack pine logs, estimates of the value of the pulp may be obtained.

A slight increase in pulp yields during storage was very probably due to the action of *P. gigantea*.

Increases in the percentage of decay are correlated with decreases in burst, tear, tensile strength, caliper, opacity, and probably folding endurance. These changes all result in poorer quality and a weakened pulp inferior to that made from noninfested wood.

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Paper Machine Inlet Performance in Relation to the Fourdrinier Wire

HERBERT C. NELSON

Much has been written in a general way about the design and performance requirements of wet-end equipment. This paper presents specific information from the field and laboratory in an attempt to facilitate a better understanding of wet-end operation. The general requirements of a paper machine inlet are reviewed in terms of its function and hydraulic performance. Field measurements that characterize specific flowspreaders and slice performance data obtained in both the laboratory and the field are presented. This includes a description of the relationship existing between slice setting and jet angle which is of interest to both the designer and operator.

THE principles and practices of papermaking have largely developed as an art over the last several centuries. In ancient times these practices were handed down from father to son through a long line of family ancestors. In more recent times they have been passed on from one papermaker to another. Following the industrial revolution and particularly during the last two or three decades, requirements of our modern and competitive society have placed such demands for greater efficiency, greater flexibility, and higher speed on process equipment that the development of this art has been inadequate. A general feeling has developed throughout the industry that a science of papermaking must supplement this art if real and continued progress is to be made in process and product improvement. This, of course, requires an understanding of basic principles underlying all aspects of the process.

The need for better understanding of wet-end operation was emphasized at Appleton, Wis., in 1954 (*1*) and then re-emphasized more recently in Montreal, Can. in 1956 (*2*). Engineers and scientists, many from within the industry but also some from without, have responded with a steady flow of published material. No effort will be made here to review this literature. In general, it calls attention to design and performance requirements of wet-end equipment based on existing knowledge in the general field of fluid mechanics. Some of the published information has been specific enough to be of real value to both the designer and operator.

Several years ago a program was established within our own research and development organization to learn more about wet-end operation, to search for related technology in other fields and apply this to paper process problems, to evaluate existing equipment in a search for points of weakness and strength, and to make improvements in old and new equipment where this was both possible and desirable. A complete summary of accomplishments would be beyond the scope of this paper even if it were restricted to those relating only to inlet performance, and much of it would be repetitious since others have reported similar work. Instead, just a few results assumed to be of real interest and value to the industry have been selected for presentation. They include:

1. Field evaluation data which characterize two types of flow spreader.
2. Field data that demonstrates the effectiveness of the distributor roll as a means for correcting bulk flow defects.
3. A description of an experimental study relating slice setting and jet performance.
4. Field data that call attention to the effect of temperature stress distortion on slice performance.

THE INLET

The inlet of a paper machine should perform at least three major functions whether it is used to produce newsprint, bookpaper base sheet, or fine papers:

1. It should accept a furnish from the fan pump system and distribute this uniformly across the machine. This, supposedly, is accomplished with the flow spreader.
2. It should disperse fibers to produce a homogeneous suspension of fibers in water, or if a dispersed condition already exists when the furnish arrives at the inlet, this condition must be maintained. A variety of agitators or turbulence generators are employed for this purpose, among which are included perforated plates, distributor rolls, and over-and-under baffles.
3. It must present this stock suspension to the wire at the proper consistency and in the form of a wide jet of uniform thickness without local flow defects. This should be accomplished by the slice.

Through the years, paper machine inlets have assumed a variety of sizes and shapes, but they all perform essentially the same functions as those listed above.

THE FLOW SPREADER

Flow spreading of good quality and the elimination of cross currents from headbox flows are frequently referred to as being essential requirements for good inlet design and performance. They certainly are reasonable requirements. Those of us who are familiar with the principles of fluid mechanics and hydrodynamics are aware of problems experienced in wind- or water-tunnel test sections because of defects in approach flows. It is natural then to expect similar experiences with paper machine inlets particularly when these defects occur in flows approaching the slice. So, we insist that designers adhere regidly to principles of good hydraulic practice when designing inlet structures. This is essential if the ultimate is to be achieved in quality of flow both within the headbox and on the

HERBERT C. NELSON, Fluid Mechanics Laboratory, Research and Development, Kimberly-Clark Corp., Neenah, Wis.

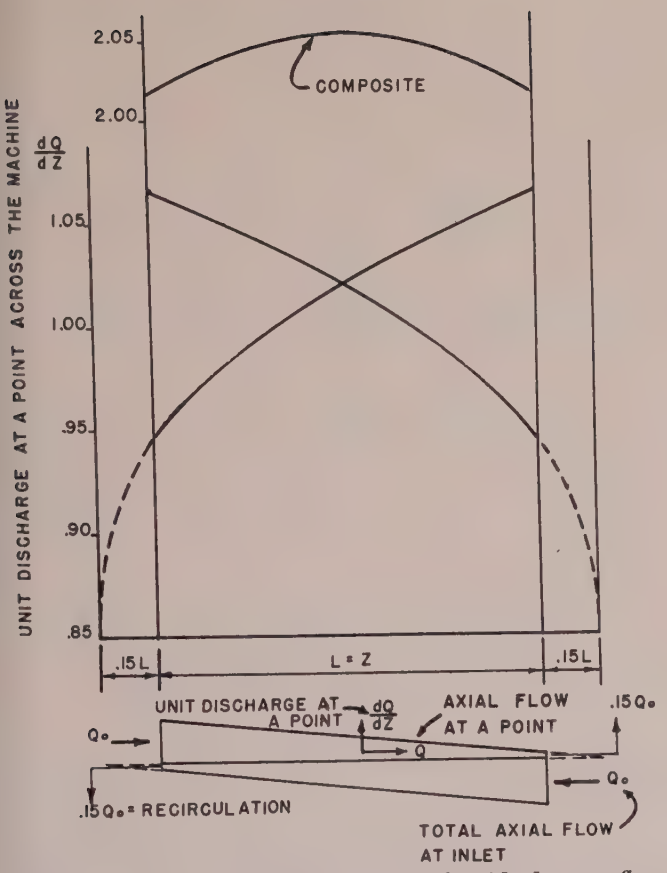

Fig. 1. Typical performance curve for ideal cross-flow spreader (adopted from Steenberg and Pettersson analysis)

wire. It is not difficult to recognize the severe nature of these performance requirements placed on flow spreaders, particularly those for high-speed machines, when we realize that to achieve the quality of flow desired this equipment must accept stock from the fan pump system usually through a round pipe approximately 24 to 36 in. in diameter, and provide a transition of flow from this circular section to a rectangular section as wide as the inlet and as deep as the headbox pond. This width may range up to 30 ft. and the pond depth to 36 in. on a modern high-speed machine. Furthermore, this stream must have vertical and horizontal velocity and fiber distributions that are essentially uniform as it flows through the headbox toward the slice.

Fig. 2. Flow spreader discharge contains cross-machine velocity components

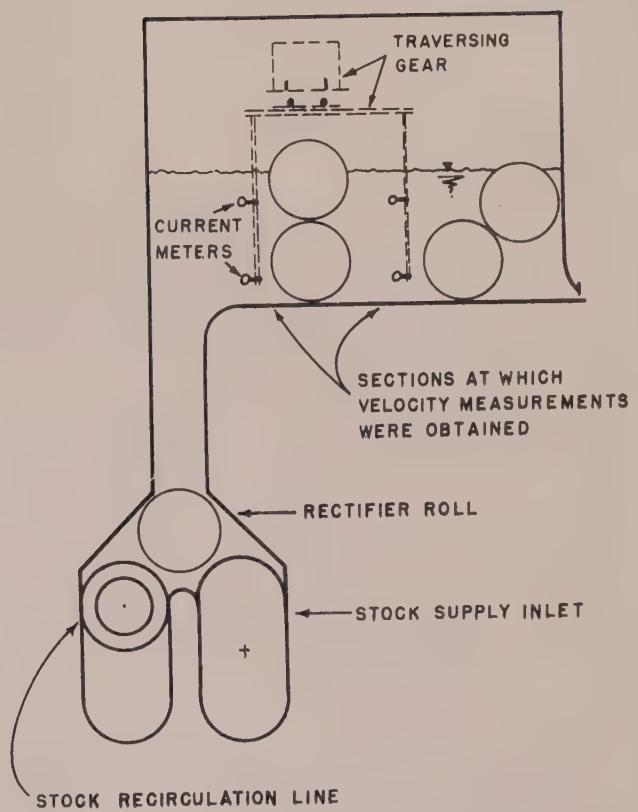

Fig. 3. Features of inlet on machine "A"

The paper machines which make up our production capacity provide typical examples of many flow spreader and inlet types which are available to the industry. One of the objectives of our research studies was to answer these questions: Just what are the characteristics of some of our modern flow spreader equipment? How does it perform in the field? Can it be improved? How rigid must our specifications be?

THE CROSS-FLOW SPREADER

One of the better and more popular flow spreaders available for use on conventional high-speed paper machines is that of the cross-flow type. Details of the design and performance characteristics of this equipment are truly a study in "manifold" flows. A familiar and simple example of the manifold is a wire or felt shower-pipe with tapped holes or shower nozzles distributed at frequent intervals along its length and either dead ended or provided with means for recirculating a portion of the total through flow at the other end. No extensive review of the theory involved in manifold flows will be presented here. The fundamental problem has been discussed by Keller (*3*) and McNown (*4*). More recently Steenberg and Pettersson (*5*) and also Baines, Nicholl, Cook, and Mardon (*6*) have applied theories of manifold flow to the analysis and design of flow spreaders. Only a general understanding of manifold flow characteristics is necessary for this discussion.

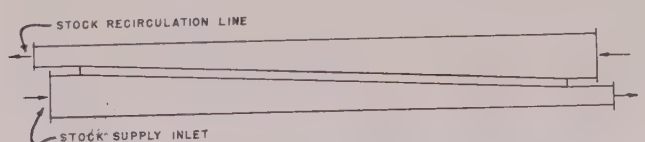

Fig. 4. Cross-flow spreader, machine "A," recirculates a portion of stock to fan pump suction

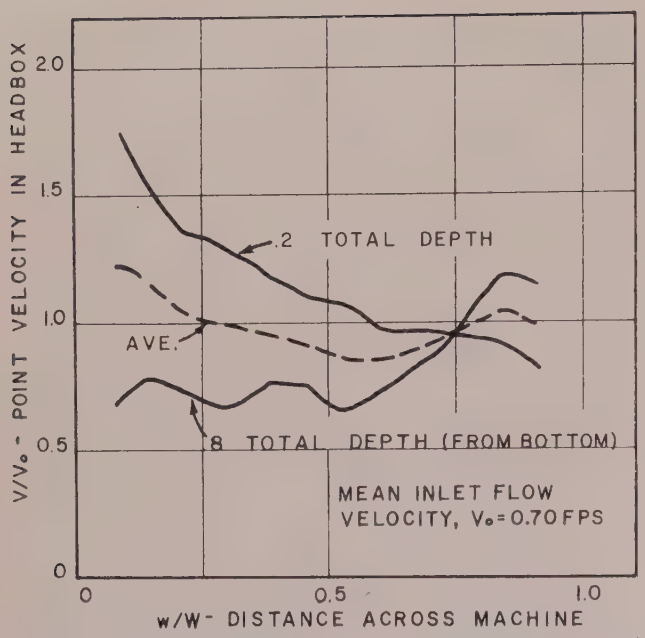

Fig. 5. Velocity distribution across flow-box when 8.4% of maximum total flow is recirculated

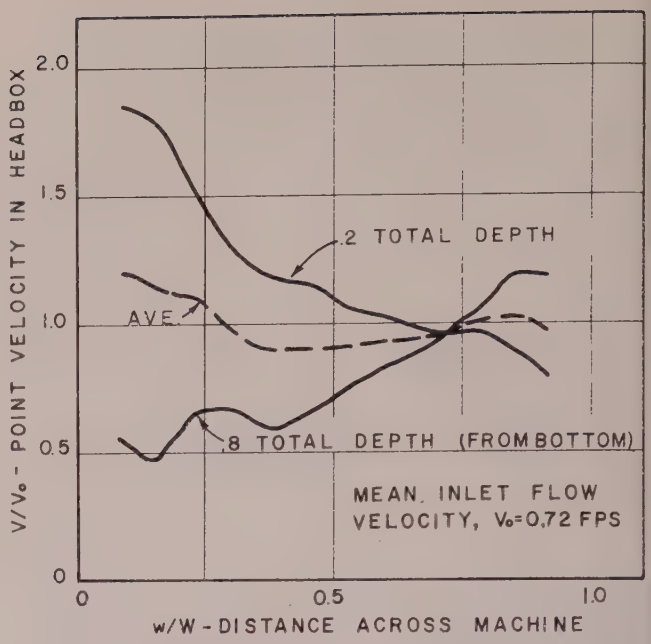

Fig. 6. Velocity distribution across flow-box when 6.3% of maximum total flow is recirculated

The "manifold effect" is characterized by a rising pressure gradient and an increasing distribution of discharge in the direction of flow for a manifold of uniform cross section and uniform orifice area distribution along its length. The rising pressure gradient results from pressure recovery achieved as a portion of the total fluid is discharged through side outlets and the remaining axial flow loses velocity. Of course, it follows then that increased rates of discharge result from increased pressures which occur along the manifold length. Two design techniques that are used to compensate for this characteristic are:

1. The use of a continuously reducing cross-sectional area along the length of the manifold. When properly designed this will produce essentially uniform pressures and discharges through a slot of uniform width.

2. Holes of different size and spacing or slots of varying width along the length of a manifold produce essentially uniform discharge distributions when properly designed. However, a pressure gradient and nonuniform velocity distribution is still maintained from end to end.

There exists a second undesirable characteristic of manifold flow that may be considered a problem source in flow spreader applications unless elaborate steps are taken to correct it. That is, velocity filaments issuing from the discharge slot or holes have a component in the direction of mean axial flows within the manifold.

In an attempt to overcome these manifold characteristics, cross-flow spreaders are generally so designed that half the total flow is introduced from each side of the machine. Each spreader element is of tapered construction with the large end at the inlet side, and one is essentially a mirror image of the other. Frequently a by-pass or recirculation feature is added through which a portion of the stock within each half of the flow spreader is recirculated back to the fan pump system. This effectively extends the length of the manifold and allows the flow spreader to perform in a more linear portion of the discharge distribution curve.

A typical performance curve for an ideal, uniformly tapped cross-flow spreader with linearly decreasing cross-sectional area, adopted from the analysis presented by Steenberg and Pettersson (*5*), is schematically shown in Fig. 1. Not all flow spreaders are apt to perform or even be designed exactly as this one. However, it does serve as a model to show anticipated performance characteristics of the cross-flow spreader as a type. It is observed that a linearly decreasing cross-sectional area in practice can overcorrect inherent manifold effects. Hence, a relatively high unit discharge from each spreader element will occur at the inlet end rather than the dead end. It is further observed that a more linear portion of the discharge distribution curve is utilized through recirculation of a portion of total flows. Finally, it is observed that the composite distribution of discharge for this ideal flow spreader is relatively uniform.

The effect of axial flow components on discharge from each flow spreader element is schematically shown in Fig. 2. It can be expected in practice that the resulting mass transfer of fluids will modify the composite discharge distribution curve shown in Fig. 1 and will cause some sort of secondary motion, particularly at the edges.

HYDRAULIC MEASUREMENTS ON CROSS-FLOW SPREADERS

Machine "A" is a modern high-speed machine equipped with a cross-flow type of flow spreader, an air-pad flow-box, or air-cushioned flow-box as some prefer to call it, and a slice section with vertical headwall and flexible vertical slice bar for the top lip. Distributor rolls are stacked, and by-passed stock from the end of each half of the cross-flow spreader is recirculated to a point ahead of the fan pump. This machine is designed to run in the 2000 to 2500 f.p.m. range. General features of this inlet and flow spreader are shown in Figs. 3 and 4. Notice the familiar tapered construction of each spreader-half.

Velocity measurements were obtained continuously

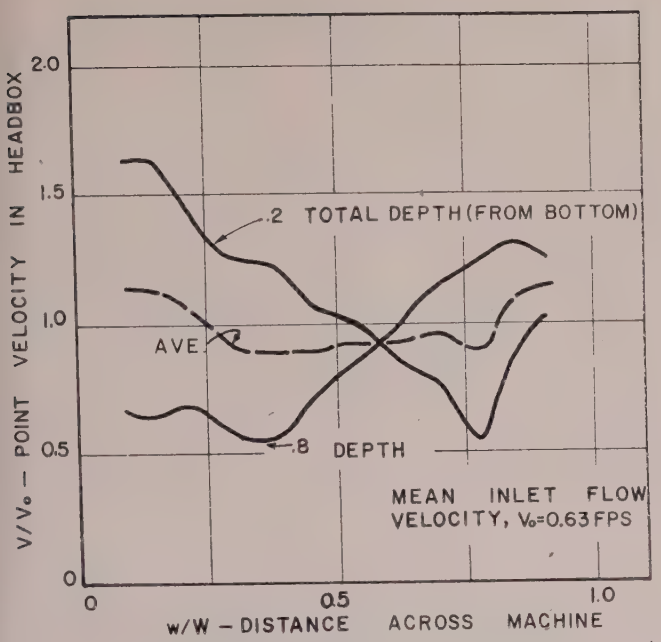

Fig. 7. Velocity distribution across flow-box when 0% of maximum total flow is recirculated

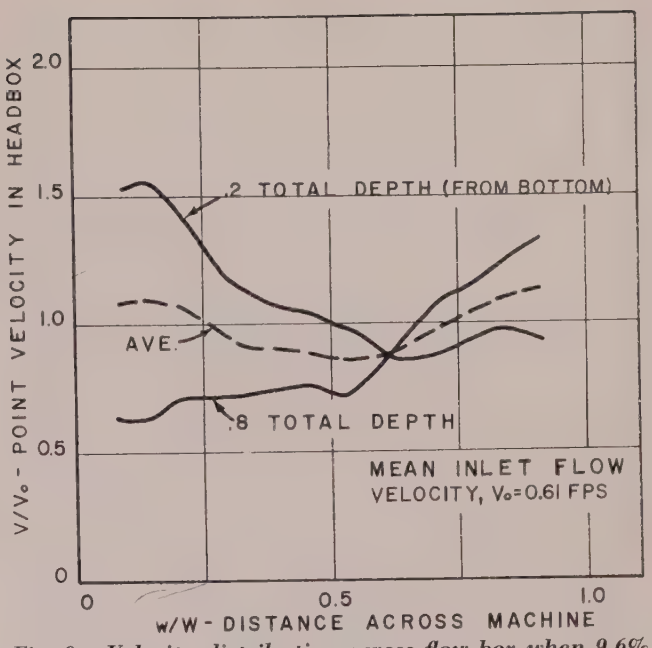

Fig. 9. Velocity distribution across flow-box when 9.6% of 80% maximum total flow is recirculated

across this machine at two levels in the pond as indicated in Fig. 3. Studies involved a variety of machine settings including two pond depths, at least two rates of discharge equivalent to different machine speeds, and several rates of recirculation from the ends of the two cross-flow spreader elements. The instrumentation used to obtain essential data is described in a later section.

A number of measured velocity distribution curves are shown in Figs. 5 through 12. The solid line graphs are plotted as a ratio of point velocity to mean inlet flow velocity in each case to facilitate comparisons between machines and among results obtained within a given machine. All distances across the machine are expressed in terms of a portion of the total width for similar reasons. Now, the general shape of velocity distribution curves observed in Fig. 5 is typical of all data obtained from this machine irrespective of machine setting. Figures 5, 6, 7, and 8 show the effects of different percentages of stock recirculation. Figure 9 is comparable to Fig. 5 in every respect except that it involves a lower discharge rate equivalent to a lower speed. Figures 5 and 10 show the results of almost identical conditions except for pond level at the higher discharge rate, whereas Figs. 9 and 11 show comparable results at a lower rate. Identical machine conditions and flow-through rates existed for the results presented in Figs. 10 and 12, except that the distributor roll over the cross-flow spreader had different directions of rotation.

It is quite apparent that velocity distribution in this inlet is strongly influenced by some inherent spreader characteristic. The shapes of these curves are very

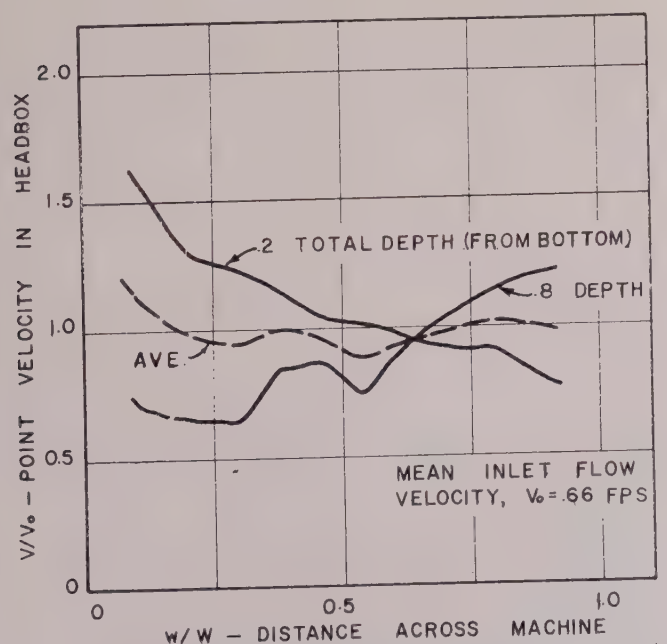

Fig. 8. Velocity distribution across flow-box when 17.5% of maximum total flow is recirculated

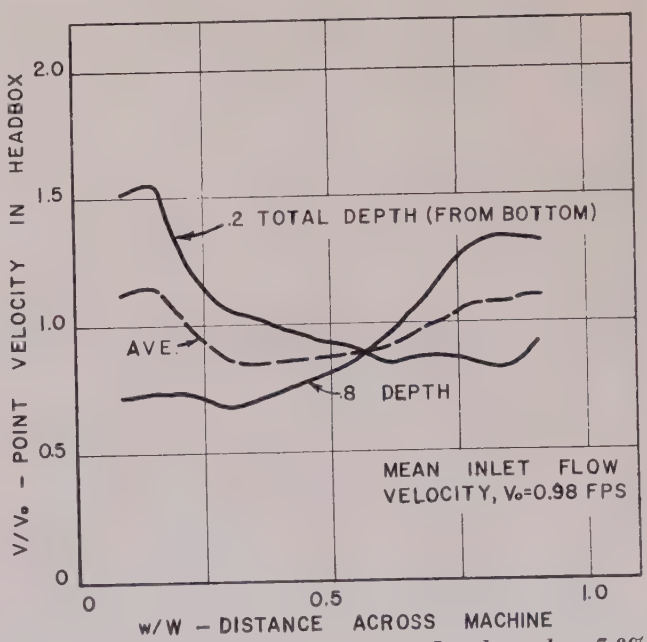

Fig. 10. Velocity distribution across flow-box when 7.8% of maximum total flow is recirculated, and pond level is reduced by 45%

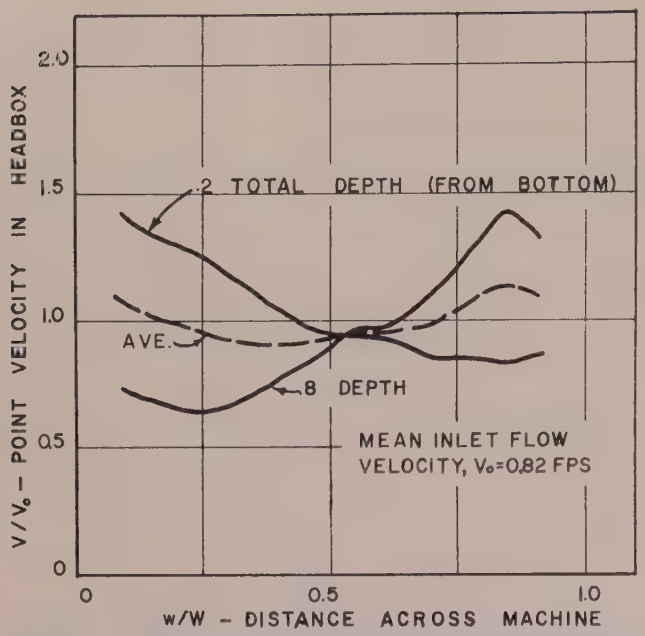

Fig. 11. Velocity distribution across flow-box when 7.8% of 80% maximum flow is recirculated, and pond level is reduced by 45%

much like those shown in Fig. 1. However, contrary to what one would expect, recirculation did not significantly affect spreader performance. In fact, the shapes of velocity distribution curves and the ranges of velocity distribution defects are essentially identical for all discharge rates, recirculation rates and mean inlet flow velocities included in this series of studies.

Although large variations exist in velocity distribution across the machine at a given level in the pond and also between levels at a given station across the machine, mean flow distribution is relatively uniform. In Fig. 13 curves are shown which represent averages between velocities at the upper and lower levels for three conditions previously described in Figs. 7, 9, and 10. This mean flow distribution is certainly quite good considering the large local velocity differences that it includes. It is characterized by a downward rather than an upward bow, however, as predicted for the ideal spreader of the Steenberg and Pettersson analysis.

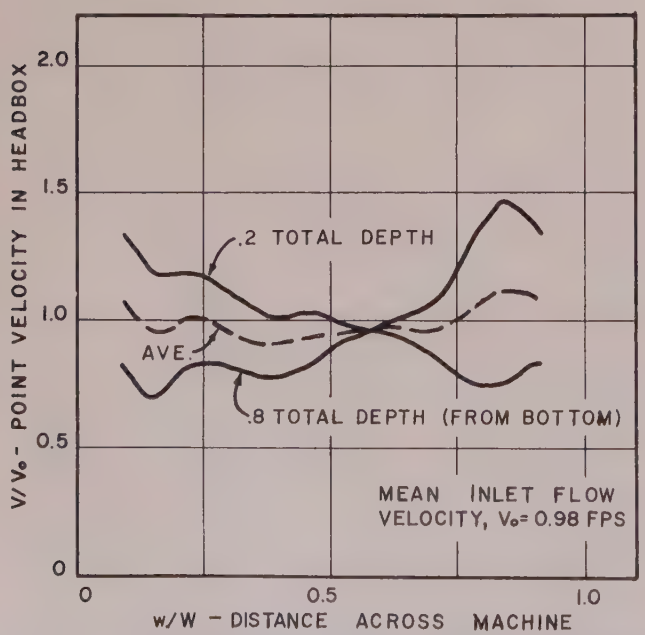

Fig. 12. Velocity distribution across flow-box when 7.8% of maximum total flow is recirculated, pond level is reduced and flow spreader rectifier roll is reversed

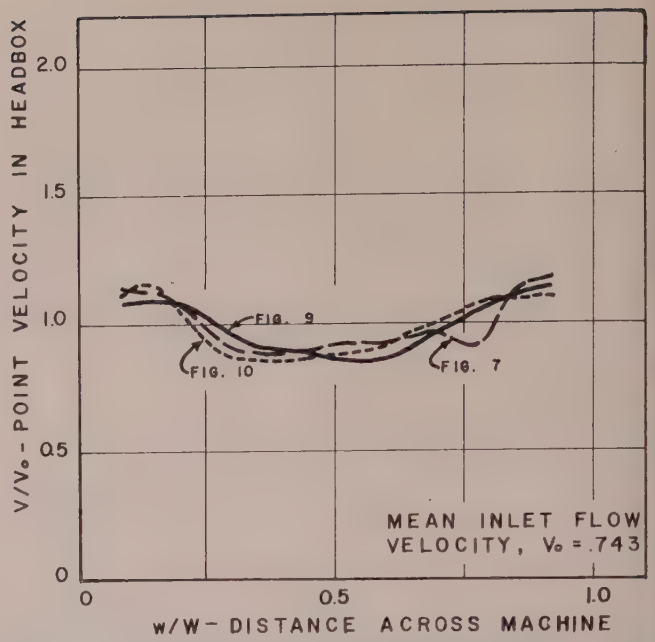

Fig. 13. Average velocity distributions from Figs. 7, 9, and 10

A logical question to ask at this point would be, "Do other flow spreaders perform in this manner, or is this just a characteristic of one particular machine?" Machine "B" is equipped with an inlet that has a cross-flow spreader, an air-pad flow-box, single distributor rolls, and a contracted nozzle at the slice with vertical slice bar for a top lip. The by-pass from one spreader element turns through 180° and enters the supply line for the other element. Machine "B" is about $^2/_3$ the width of machine "A" and is designed for a speed range of 1800 to 2000 f.p.m. General features of the inlet are schematically shown in Fig. 14. Again velocity distributions were measured at two depths. The results appear in Fig. 15. In this instance, discharge rate was equivalent to a wire speed of 1900 f.p.m., and the mean headbox flow velocity was about 0.67 ft. per sec. A characteristic nonuniform velocity distribution exists much the same as before except that the curves are skewed to one side and have a much more pronounced "reverse tail" at each end. Data obtained at two additional depths permitted cross plots of vertical veloc-

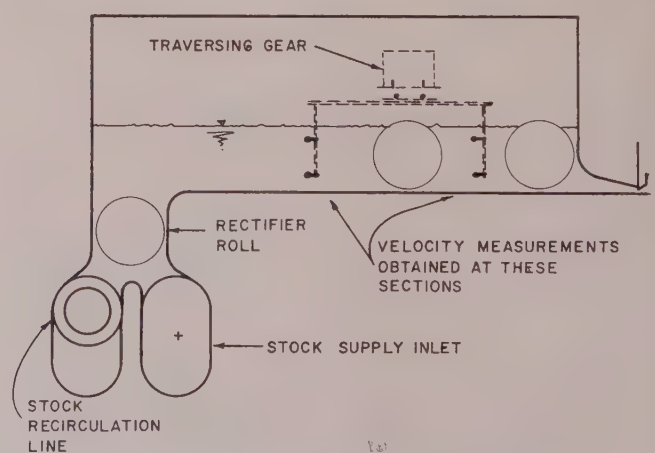

Fig. 14. Features of inlet on machine "B"

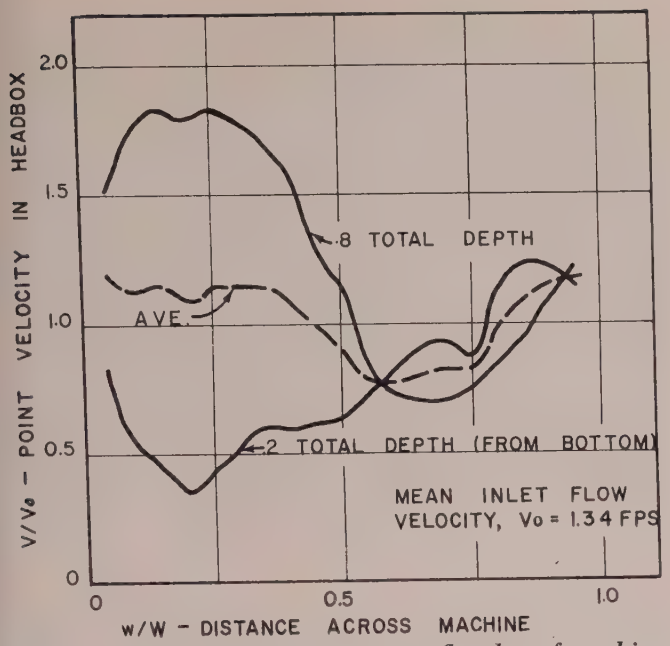

Fig. 15. Velocity distribution across flow-box of machine "B" at maximum total flow-rate

ity distributions. Several of these are shown in Fig. 16. Notice how the higher velocity flows shift levels at successive sections across the machine. A better average curve was obtained from the four traverses made on this machine than from the two made on machine "A." This is shown in Fig. 15.

THE GUIDE VANE FLOW SPREADER

Dissatisfied with the performance of flow spreaders existing a number of years ago, we, through our research, development, and engineering facilities decided to develop our own equipment. The result was a wide angled diffuser-type flow spreader (7) with adjustable guide vanes at the throat to permit control over flow distribution to the inlet. Let us look at the results of a survey made on machine "C," which is equipped with a K-C flow spreader, an air-pad flow-box, single distributer rolls, and a slice section that includes a contracted nozzle and vertical slice bar for a top lip. This machine is designed for speeds of 1500 to 1800 f.p.m. The physical features are schematically shown in Fig. 17. The velocity distribution presented in Fig. 18 was obtained from machine "C" and is typical of what can be obtained with this flow spreader when properly designed and adjusted for optimum guide vane setting. Only one curve is shown here at about 0.8 of pond depth because the second current meter failed to operate shortly before this measurement was obtained. A

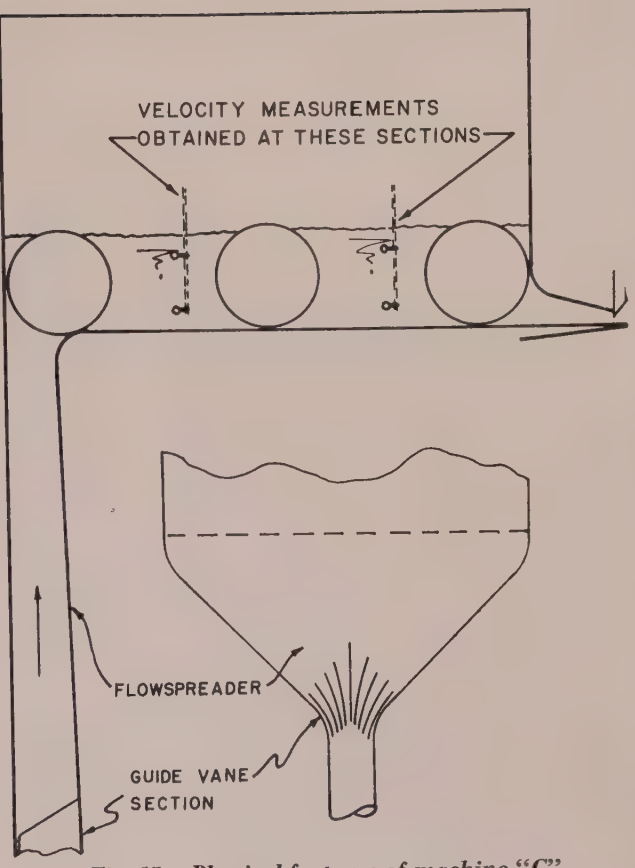

Fig. 17. Physical features of machine "C"

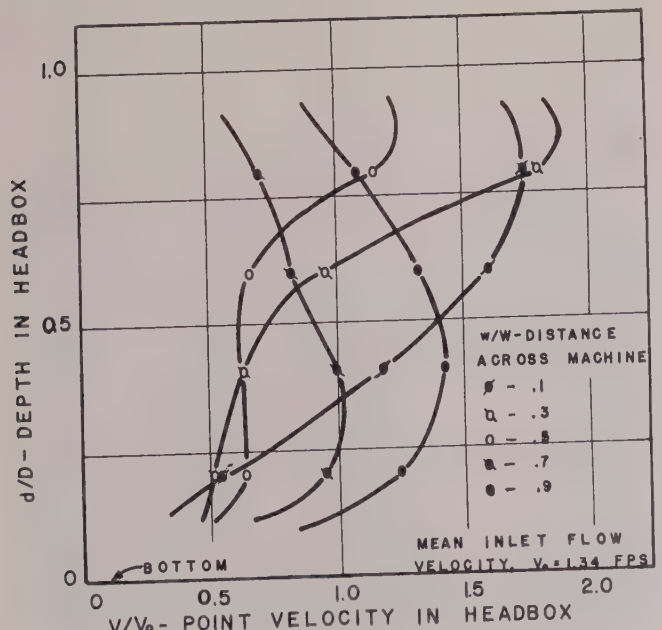

Fig. 16. Vertical velocity distributions at five sections across machine "B" at maximum total flow rate

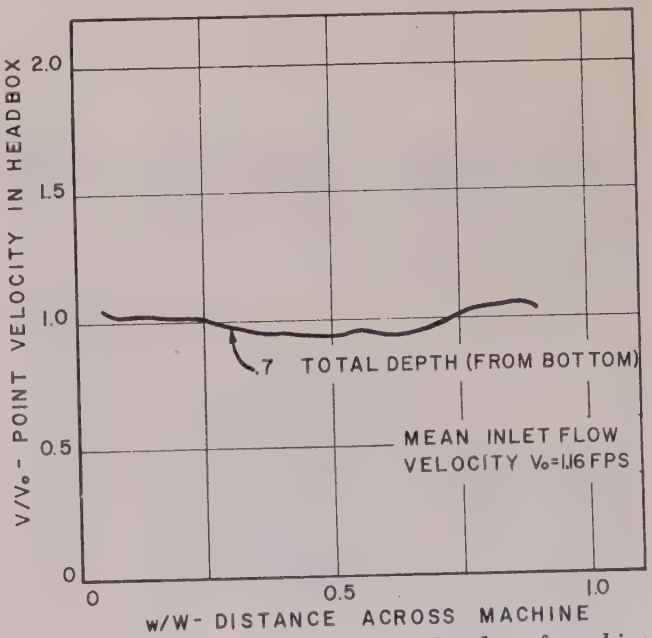

Fig. 18. Velocity distribution across flow-box of machine "C" at maximum total flow rate, good guide vane setting

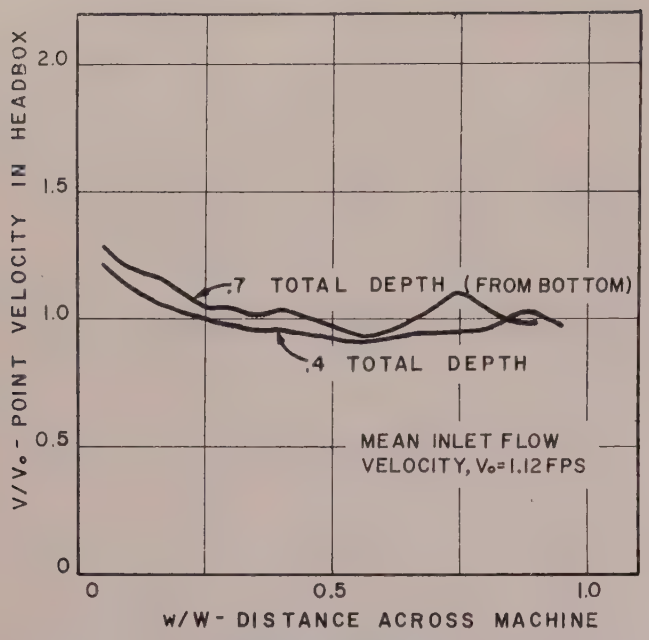

Fig. 19. Velocity distribution across flow-box; guide vane setting is not optimum

previous set of data obtained at two depths, but for a guide vane setting that was not optimum, is shown in Fig. 19. Notice that although velocity profiles across the machine are skewed they are parallel. High flows and low flows exist at the top or bottom on the same side of the machine rather than opposite sides. Subsequent vane adjustments produced the relatively uniform distribution shown in Fig. 18. Equivalent machine speed for this data was 1500 f.p.m.

Velocity measurements obtained on models, Fig. 20, show that exceptionally good flow distributions can be obtained on this equipment without benefit of distributor rolls to aid in producing uniform flows. Data obtained at sections shown in Fig. 20 are presented in Fig. 21.

INSTRUMENTATION FOR VELOCITY MEASUREMENTS

A word should be said about the instrumentation used in obtaining information such as this before we proceed further with the discussion of other data. Velocity measurements were obtained simultaneously

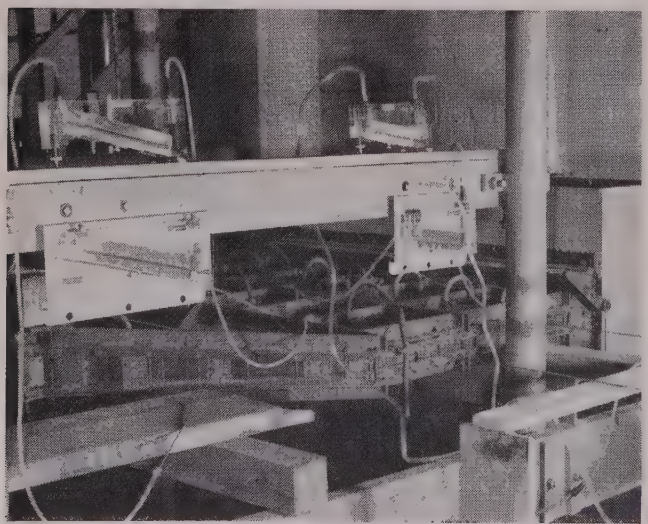

Fig. 20. The model with locations of cross sections indicated at which velocity distributions were obtained

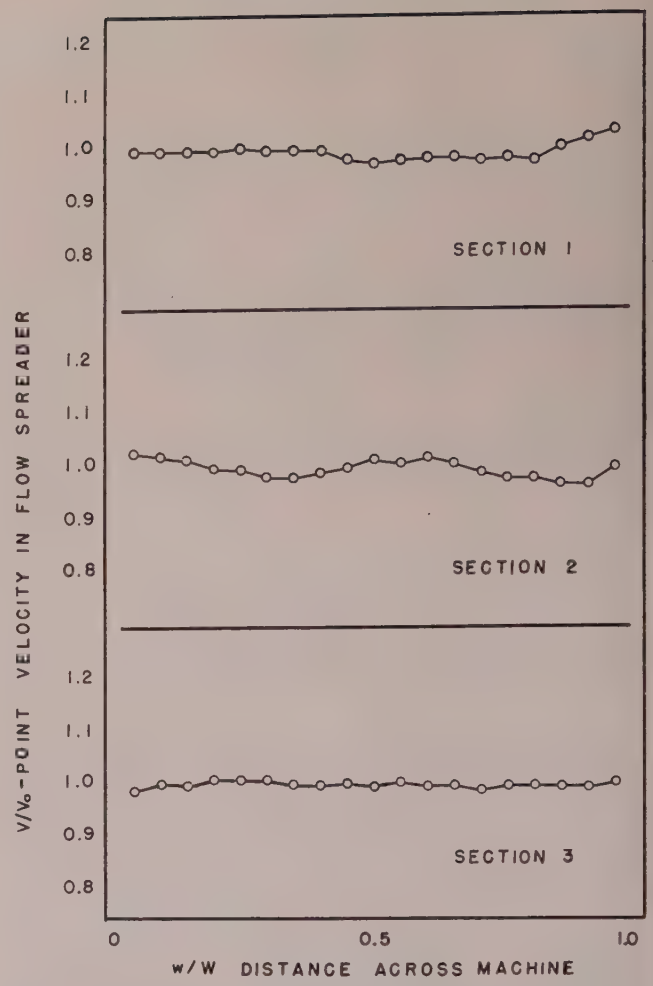

Fig. 21. Velocity distributions across a model flow spreader at three different cross-sections

at the two levels with two Pygmy Gurley current meters, model 625F (*8*). This instrument measures average values of flow velocity and will detect very low frequency velocity fluctuations that have periods of several seconds. Advantages of this equipment are that it is commercially available, relatively small in size, durable, reliable, and not readily affected by bits of debris in the form of wood fibers which always seem to be present in the fan pump system regardless of how well the machine is flushed before work is begun.

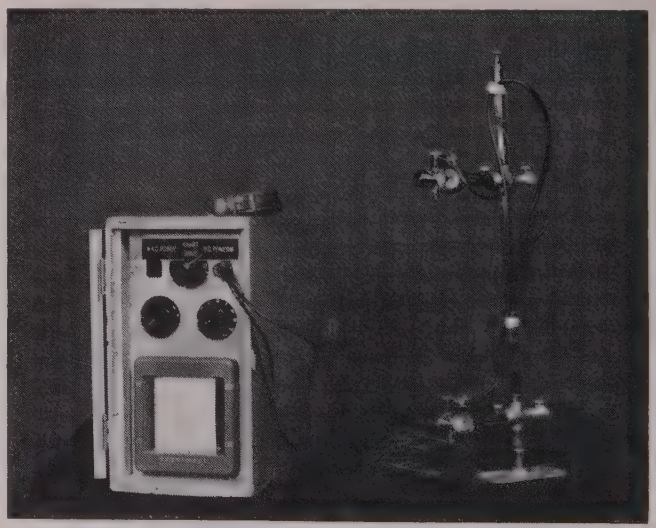

Fig. 22. Current meters and recorder equipment

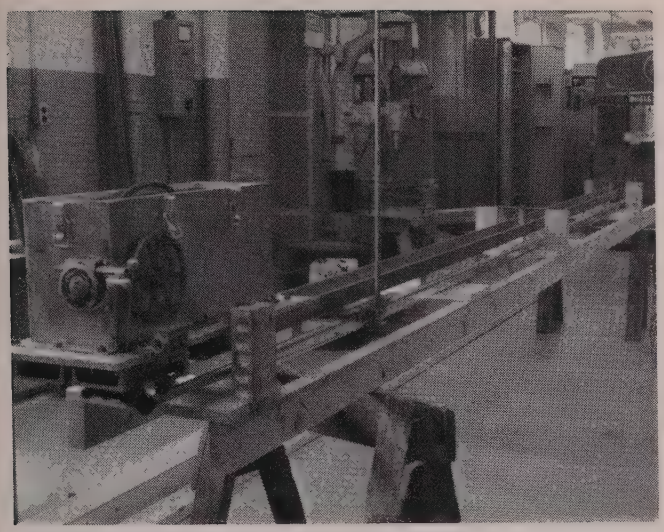

Fig. 23. Traversing mechanism

Disadvantages are that it does not measure high frequency velocity fluctuations, it cannot be used to determine direction of velocity filaments, and it can only be used for measurement of horizontally oriented flows.

The current meters are mounted on a vertical shaft which can be traversed across the inlet continuously or, if one so desires, it can be stopped at selected points while measurements are obtained. Traversing is accomplished through a variable speed motor transmission unit housed in an air-loaded head box of its own to prevent submersion in the event that the inlet is flooded during startup. The traversing mechanism and speed control can be operated remotely from a central data collection center. Signals from the current meters are recorded on separate strip recorders

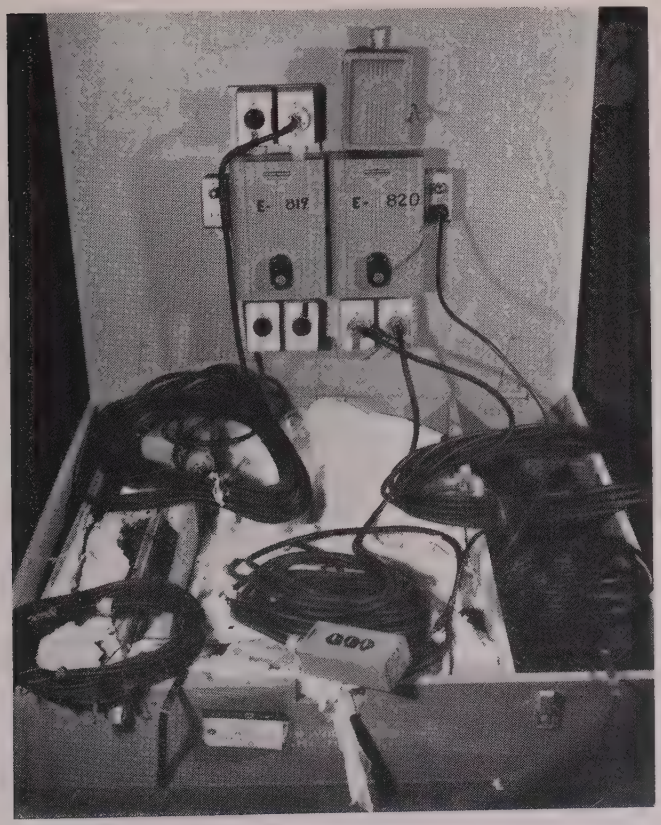

Fig. 24. Remote control equipment

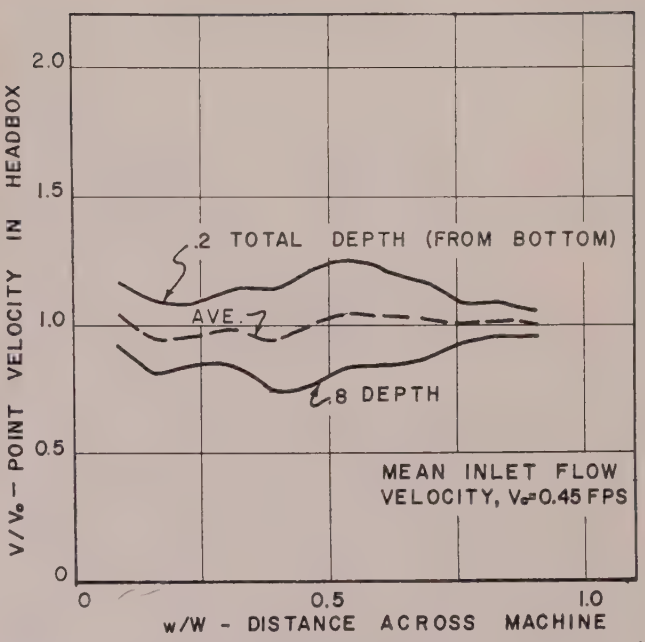

Fig. 25-a. Velocity distribution across the flow-box of machine "A," following distributor rolls

which in turn can be interlocked with the traversing mechanism or operated independently. When interlocked, the chart drive starts as the traversing carriage starts, and it stops when the carriage stops. The current meters, recorder equipment, and traversing gear together with a typical portable control panel for this equipment is shown in Fig. 22 through 24. The portable control panel is essential to success. It features color coded connecting cords and built-in means for isolating segments of circuitry that may be shorted-out with water during trials.

Water was used as the fluid medium in all these trials.

THE EFFECT OF DISTRIBUTOR ROLLS

Distributor rolls are generally used for two purposes, to agitate or disperse stock and to reduce, if not com-

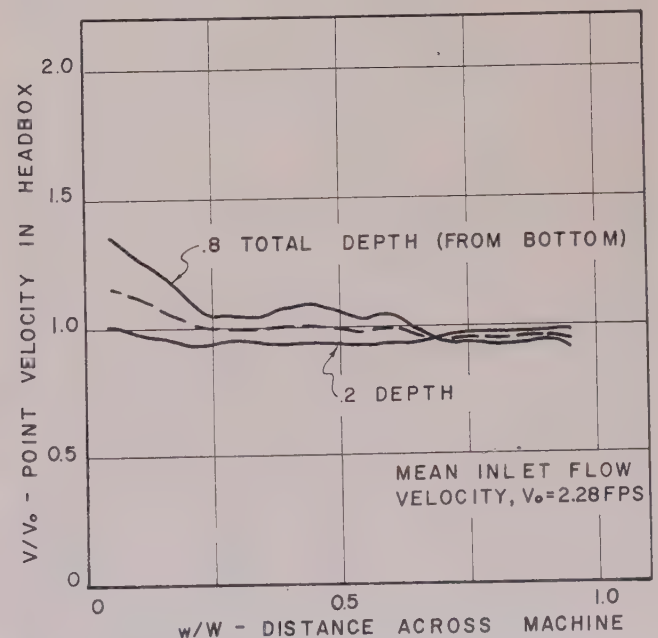

Fig. 25-b. Velocity distribution across the flow-box of machine "B," following distributor rolls

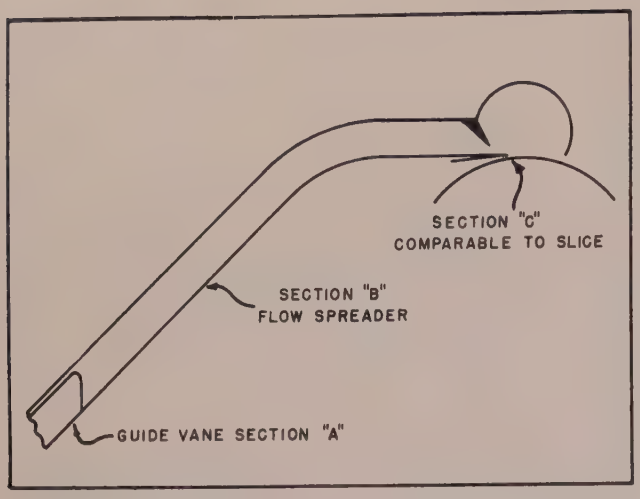

Fig. 26. Physical features of pressure forming inlet with K-C guide vane flow spreader

pletely obliterate, flow defects. In his discussion of "Flow Characteristics of Distributor Rolls and Perforated Plates" (*9*) at the 1957 TAPPI Conference in Cincinnati, Bennett demonstrated the power of properly designed rolls to even out flow defects. There are two such "barriers" to flow existing between the flow spreader and slice on machines "A" and "B." What effect do they have on subsequent velocity distribution as stock moves through the inlet?

Data obtained on both machines "A" and "B" at a position between the intermediate and slice distributor rolls, as shown in Fig. 3 and 14, are presented in Fig. 25 (a) and (b). Just one set of rolls following the flow spreader appears to have quite effectively smoothed out bulk flow defects. These curves are typical of many obtained at this position on these and other machines. The slice distributor roll should further modify persistent flow defects and improve the quality of bulk flows before they reach the slice.

It should be noted that the solidity of distributor rolls

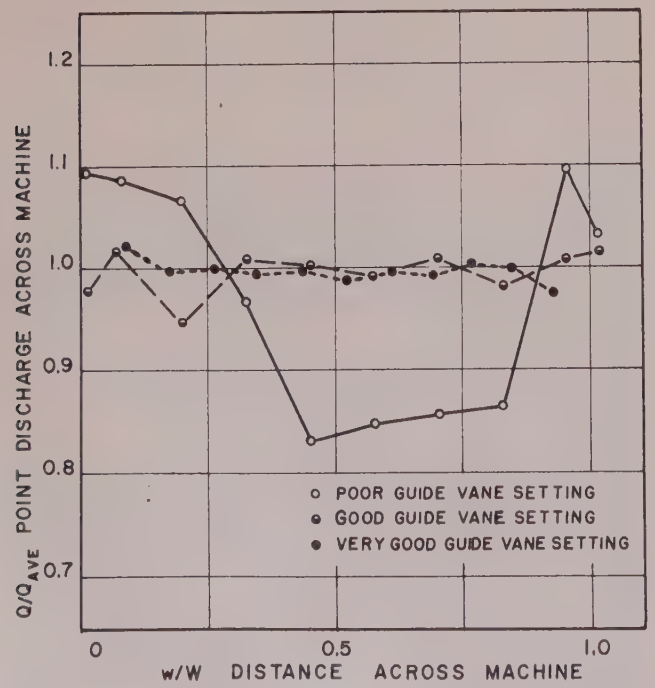

Fig. 27. Variation in discharge across pressure forming inlet due to velocity defects in the flow spreader

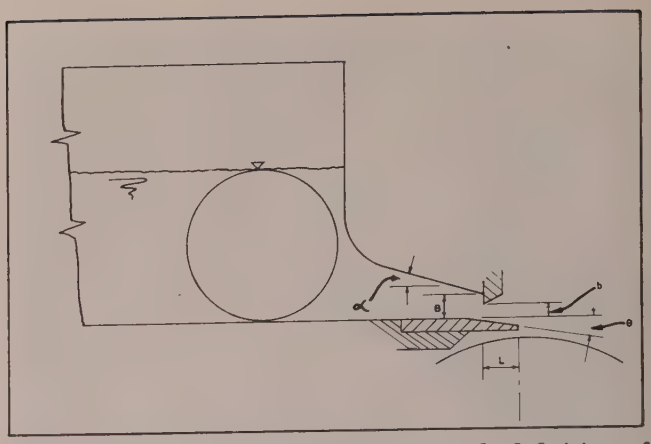

Fig. 28. One type of slice geometry with definition of terms

involved in all these studies were in excess of 50%. Most of them approximated 60%. Bennett recommends that roll solidity be less than 50%, perhaps as low as 45%, to provide adequate control of flow deflects and to simultaneously produce small-scale turbulence in a fiber suspension. Would a roll as open as 40 to 45% solidity be able to overcome the velocity difference observed in inlets on machines "A" and "B?" Suppose that they were not overcome. What would be the effect on slice performance?

The results of trials performed on a pressure-forming inlet some years ago would be of value here. General features of this inlet, which is equipped with a K-C guide vane flow spreader, are shown in Fig. 26. At point "A" there is a set of adjustable guide vanes useful in the control of flow distribution in the flow spreader "B." At "C" an appendage from the top inlet surface forms the equivalent of a slice top lip. The bottom inlet surface extends far enough to form the equivalent of an apron. Experiments were run on this machine to determine the effect of guide vane setting on slice discharge. First the vanes were set to produce an eddy in the flow spreader, and then slice discharge measurements were obtained by a mechanical sampling technique to obtain the profile presented in Fig. 27. Notice the large differences in slice discharge which occur across the machine. Later the guide vanes were adjusted to provide good quality flow spreading. The result was the relatively uniform distribution of discharge which also is shown in Fig. 27. These conditions are easily recognized to be quite different from those existing in the conventional headbox, but it does serve to emphasize the importance of flow spreading in this application and where the use of distributor rolls of more open construction is contemplated. Perhaps this experience warns us of problems to be encountered as new and different equipment is developed in the future.

FLOWSPREADER PERFORMANCE REQUIRED

How good should a flowspreader be? What level of excellence is justified? This is an extremely difficult question to answer objectively since it is so difficult to obtain really reliable quantitative data to support that answer, particularly in terms of quality in the paper produced. Some circumstance that casts doubt on results or the interpretation of results is almost always involved when comparisons are made. Speed

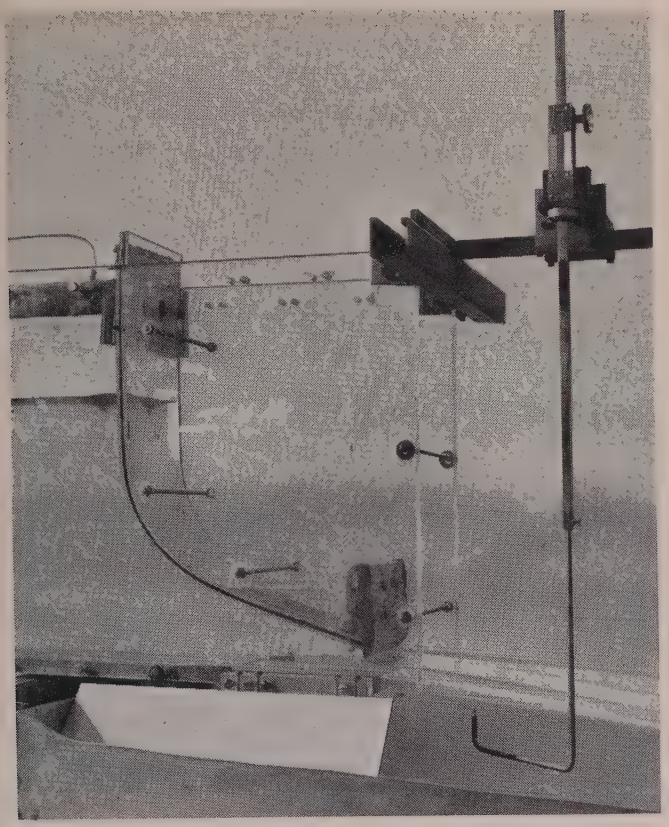

Fig. 29. Experimental equipment used to determine the jet angle–slice setting relationship

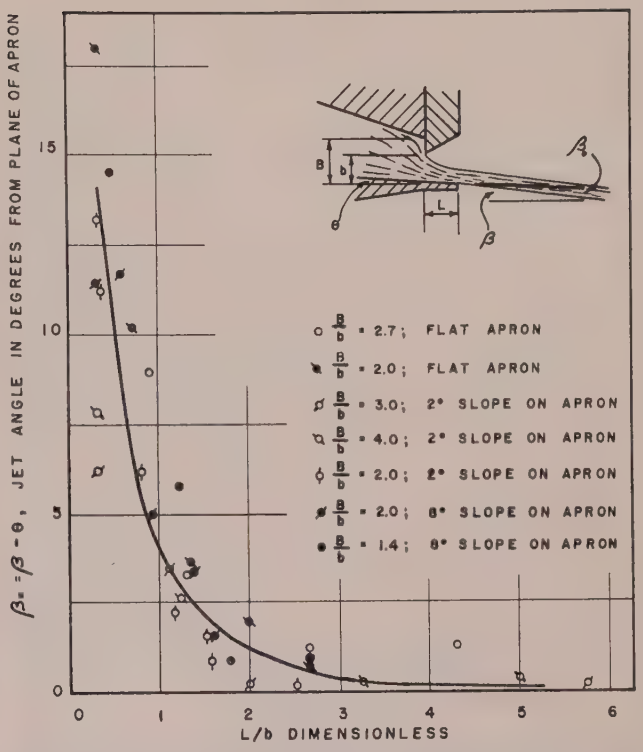

Fig. 30. Relationship between jet angle and slice setting where apron is sloped and angle is measured from the plane of the apron

differences, machine differences, other changes made on a machine simultaneously with an inlet change, etc., are usually involved in one way or another. Of the spreaders examined and compared on a roughly equivalent basis none has given outstandingly superior performance in terms of paper formation. If large differences are potentially present they are masked by the effect of distributor roll action, table roll action, table shake on the slower machines, dandy or lump breaker rolls, and by pressing.

We might say then that for the present state of development in the art which includes the air loaded inlet with two or three banks of perforated rolls, the conventional fourdrinier table and speeds somewhat in excess of 2000 f.p.m., "reasonably good" flow-spreading is sufficient including the equivalent of that produced by the cross-flow spreader described above. However, if systems are "opened up" or "cleaned up" by using more open distributor rolls, by removing them completely or if higher inlet stock velocities are utilized, then greater excellence will probably be required and justified.

SOME THOUGHTS ABOUT THE SLICE

The slice of a paper machine is an extremely important and sensitive operating tool. A complete understanding of its function and performance characteristics is important to the operator in translating "know-how" from one machine to another as well as in the performance of his day-to-day operation, and important to the designer in translating specific performance features from one machine to another.

Control of water in the sheet, or control of head box consistency if one prefers, is one very important function of the slice. The basic continuity and orifice equations

$$Q = VA \tag{1}$$

$$V = C\sqrt{2gh} \tag{2}$$

relate those terms involved in the control of discharge through the slice. Since the head, h, and stock velocity, V, are dictated by wire speed, then slice discharge, Q, is a function of the slice opening only. This presumes that sufficient water will always be supplied to the headbox to maintain the head at its specified level. The mean sheet weight, of course, is determined by the rate at which stuff is supplied to the system.

Control of sheet weight at selected points across the machine is another function of the slice. This is accomplished by changing the area term A in equation (2) by a small amount at selected points across the machine through spindle adjustment, thereby permitting a smaller or larger quantity of fiber and water mixture to be deposited in the desired area of the wire. Cuffey (*10*) has discussed in detail some of the interactions which occur between basis weight and slice opening as these adjustments are made.

Control of the jet angle is another function that is easily recognized but one that perhaps is not always fully appreciated. The relative position of both top and bottom lips are obviously instrumental in determining jet angle. It would be both interesting and useful to know the functional relationship existing between slice setting and jet angle so that this angle could be predicted. Then operator control of the slice would not be quite so much trial and error. This relationship can be determined analytically utilizing potential flow theory and relaxation computation methods. The many possible combinations of slice geometries involved and the lengthy calculations required seemed to make

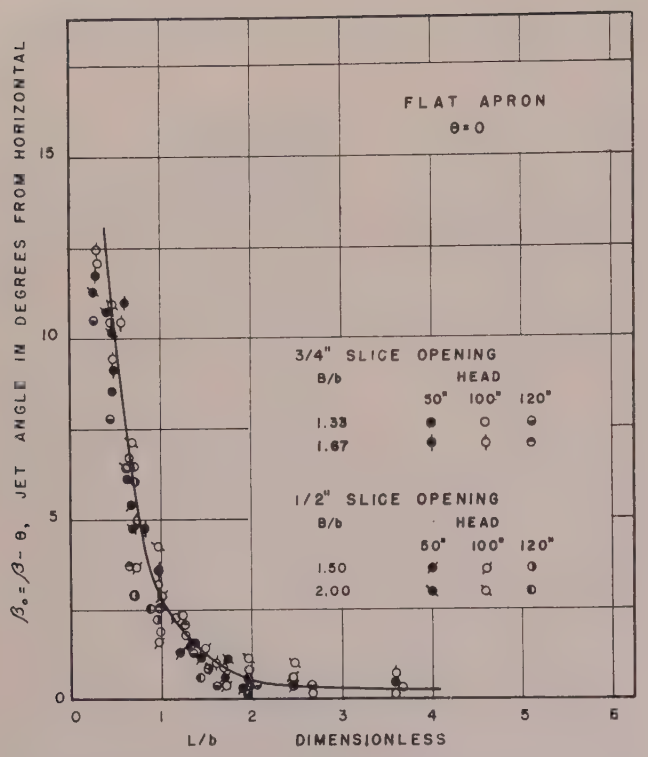

Fig. 31. Relationship between jet angle and slice setting where apron is flat and angle is measured from a horizontal plane

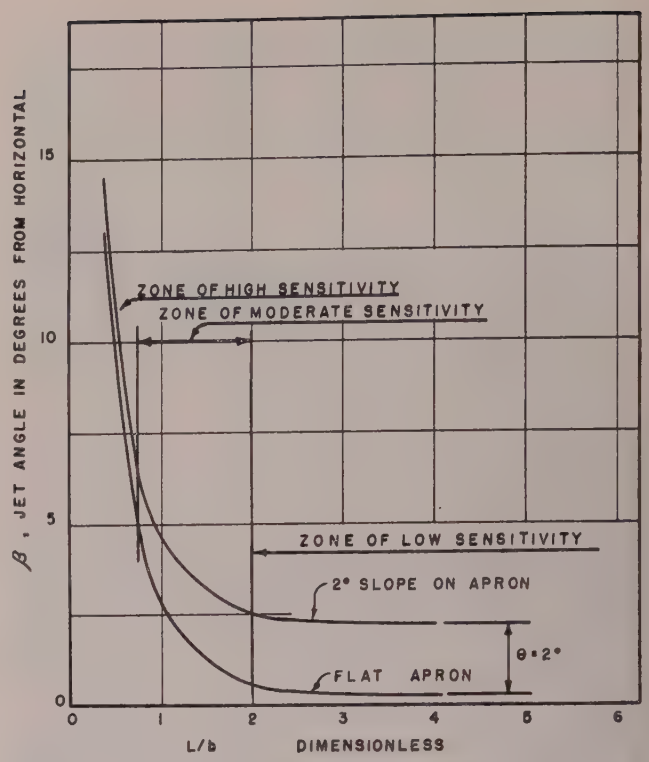

Fig. 32. Relationship between jet angle and slice setting where apron is either flat or sloped and angle is measured from a horizontal plane

this approach impractical. Instead, we used the experimental method described as follows.

In Fig. 28 is shown a typical example of one slice geometry found on machines operating between 1000 and 2500 f.p.m. Specific features include an air pad that suppresses pond levels to a fraction of the total head, a contracting nozzle, a vertical slice bar top lip which is vertically and horizontally adjustable, and an apron that is flat or slightly sloped. Symbols and terms associated with geometric features are also shown in Fig. 28. A general functional relationship relating all terms involved in the hydraulic performance of this slice and more particularly jet angle would be:

$$f_1(V, g, \rho, \mu, b, B, L, \beta, \alpha, \theta \ldots) = 0 \qquad (3)$$

In this expression, V represents flow velocity, g the acceleration of gravity, and the terms ρ and μ represent the fluid properties mass-density, and viscosity, respectively. The remaining factors are all geometric terms, some expressed as lengths and others as dimensionless ratios.

Equation (3), can be written as follows in parametric form involving only dimensionless groupings of these factors.

$$f\left(\frac{V^2}{gb}, \frac{Vb}{\mu/\rho}, \frac{B}{b}, \frac{L}{b}, \beta, \alpha, \theta\right) = 0 \qquad (4)$$

Now, the first term can be recognized as a Froude number which involves the force of gravity and its effect on free surface phenomenon. Gravity should not significantly affect jet angle provided the headbox water surface is far from the slice and as long as we are concerned only with the angle assumed by the jet shortly after it leaves the bottom lip where all internal stresses have been relieved. The second term, $Vb/\mu/\rho$ is the Reynolds number. This should not be of any consequence as long as viscous effects are minor. The term θ will contribute a fixed quantity to the jet angle for any one machine. Then we could consider the jet angle to be the sum of two parts, $\beta=\beta_0+\theta$, where β_0 is functionally related to all remaining terms in equation (4), except θ which is a constant. A change in relative slice opening involving slice opening and top lip projection should not materially affect jet angle as long as the ratio B/b has a value much larger than unity. However, as this ratio approaches the value of one the jet angle will become very sensitive to changes in B/b at low values of L/b. The term α can assume a wide range of values from near 0° up to and including 90° when expressed in terms of degrees. Let us assume that the value of α is fixed for the present and restrict our discussion to one geometry, as shown in Fig. 28. The functional relationship for jet angle can then be written as:

$$\beta = f_3\left(\frac{B}{b}, \frac{L}{b}, \theta\right) \qquad (5)$$

In modified form where bottom lip slope or apron slope is assumed to contribute a fixed portion of the total jet angle it may be written as:

$$\beta = (\beta_0 + \theta) = f\left(\frac{B}{b}, \frac{L}{b}\right) \qquad (6)$$

$$\beta_0 = f\left(\frac{B}{b}, \frac{L}{b}\right) \qquad (7)$$

The nature of this functional relationship was determined experimentally on the equipment shown in Fig. 29 using water as the fluid medium. Bottom surface profiles of the jet projected from this slice model were determined for several different values of B/b, L/b, θ, and discharge rate. These profiles were then corrected for gravitational effects. Jet angles were computed and plotted as shown in Figs. 30 and 31. Although the scatter in Fig. 30 might be considered excessive, the nature of this relationship is very apparent. Part of

this scatter is due to experimental error, of course, and part of it is due to geometric changes incidentally related to apron slope. The same trend is observed with much less scatter in Fig. 31 where all data were obtained using a flat apron lip.

SIGNIFICANCE OF JET ANGLE

The modern high-speed machine fourdrinier is generally arranged with the forming board lip about 8 in.

Fig. 33. Flow on wire when $L/b = 1.5$

plus or minus a few inches from the breast roll centerline and with the apron lip set on breast roll centerline plus or minus a fraction of an inch. The operator normally must control the point of jet impingement to within something less than these limits, considerably less if the breast roll is not to remove water from the sheet. An understanding of the relationship that exists between jet angle and slice setting should result in a much more rational use of slice adjustment as a tool in

Fig. 34. Flow on wire when $L/b = 1.0$

machine operation.

The curves presented in Figs. 30 and 31 are duplicated as the lower curve in Fig. 32 but without experimental points. Notice that three more or less distinct regions of control sensitivity exist identified individually as regions of low, moderate, and high sensitivity. Control of jet angle is in a region of low sensitivity when $L/b > 2$. Here relatively large changes in the value of L/b are required to change the jet angle a small amount. However, the point of jet impingement changes position rapidly. This implies that the apron need not project beyond the top lip a distance of much more than twice

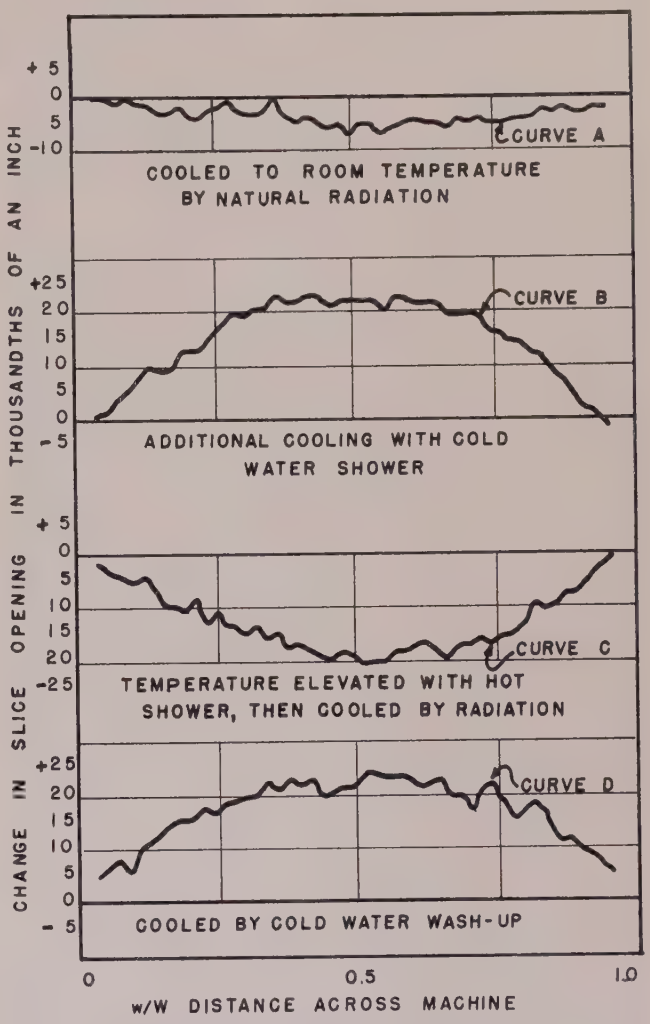

Fig. 35. Change in slice opening due to temperature stress distortion of the slice structures

the maximum slice opening to be used. The region of high control sensitivity exists where $L/b < 0.7$. Small changes in relative lip position here produce large changes in jet angle. However, the jet is pitched into the wire so steeply that the point of impingement changes slowly. This limiting ratio will be the slice setting near which water is removed by the breast roll on those machines equipped with a flat apron.

Between these extremes, $0.7 < L/b < 2$, lies the third region, one of moderate control sensitivity. Slice settings for normal machine operation fall within these limits. One point should be emphasized here. The lower curve shows the relationship between β_0 and L/b, or the jet angle for various slice settings on a machine equipped with a flat apron lip, and $\theta = 0$ in equation (6). This must be corrected for any machine that has a sloping apron. For instance, the upper curve in Fig. 32 is for a machine with an apron that slopes 2°, or where $\theta = 2°$.

There are several other factors involved in determining the exact point of jet impingement which have been ignored until now. It is obvious that once the jet springs free from the apron lip, gravity alters its direction and must be considered when predicting that point. This is particularly true at low heads and wire speeds The height of apron lip above the wire certainly affects the horizontal distance between apron lip and point of impingement as well as the period of time that gravity acts upon the jet. Presumably, the clearance between apron and breast roll can influence jet angle by virtue of its effect on pressures within the pocket between jet and wire. A close clearance results in a relatively low pressure in this pocket with depression of the jet a result. A large clearance results in just the opposite effect.

The point of jet impingement with reference to either forming board setting or breast roll location is generally considered very important to sheet formation. The data presented above together with certain necessary physical dimensions from the slice region permit the calculation of that point of impingement with reasonably good accuracy. Operating conditions or slice settings found to be desirable on one machine can be translated to others with greater confidence. This is of particular advantage when working between pilot plant and production equipment. Evaluation work is simplified when it is realized that of the many variables which exist because of variations in slice geometry and setting only a few are really important to slice performance, particularly to control of jet angle, and that these can be expressed as one or two dimensionless parameters generally applicable to all slice sections which are reasonably similar. These are just a few examples of the manner in which specific information like this can be usefully employed.

Just how important is the ability to control jet angle? Figure 33 shows flow on the wire of a machine operating at about 1300 f.p.m. wire speed when L/b = 1.5. Figure 34 shows flow conditions existing only a few minutes later when L/b = 1.0. Surface wildness of this nature becomes much more intense as speeds increase. This emphasizes the need for horizontal adjustment facilities to supplemnt those which normally provide for vertical adjustments.

TEMPERATURE STRESS AND SLICE DISTORTION

Slice distortion due to temperature stress is frequently referred to as a source of operating problems but is not so frequently recognized as being really important. In an unpublished report, Forsgren (*11*) describes specific experiences with this particular phenomenon.

A particular machine identified as machine "D" had been plagued with extreme basis weight variation and a roll building problem during startup. A routine machine startup frequently extended over a period of hours. Distortion of the slice section as a result of temperature variation was considered one possible cause and a study program was set up to determine the extent to which this could occur.

The slice opening was gaged upon shutdown and again about 4 hr. later. During this period the inlet temperature dropped from a normal operating temperature of slightly over 90°F. to near room temperature at about 70°F. The change in opening that occurred as a result of this temperature change is shown as curve "A" in Fig. 35. Curve "B" in Fig. 35 shows the change in slice opening which occurred as the inlet was cooled still further with a cold water shower from normal operating temperature to a temperature of about 50°F. This represents a temperature change of some 40°F. Next, the inlet was warmed up to about 102°F. and then allowed to cool to 82°F. The resulting change in slice opening from that at shutdown is shown in curve "C," Fig. 35. On another occasion the slice opening was determined immediately after shutdown for a machine washup and again following washup using cool, fresh water. The change in slice opening observed is presented as curve "D," Fig. 35.

This emphasizes the magnitude of slice distortion that can occur as a result of temperature variation in inlet structures. The use of cold water during washup, cold shower water, and cold water in the fan pump system upon startup are all potentially hazardous procedures and can contribute to temperature stress distortion of the slice as an operating problem. The use of cold water upon startup can be particularly troublesome since both slice opening and basis weight will change continuously until normal operating temperature has been reached. All during this time operators will frantically try to control basis weight by spindle adjustment, but when the machine finally settles down the slice will be set essentially as it was before startup.

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High-Amylose Cornstarch—Properties and Prospects

F. R. SENTI and C. R. RUSSELL

High-amylose starch, a new type of corn starch containing 50 to 60% amylose, or about twice the amount present in ordinary corn starch, is now available in semicommercial quantities, and the development of starches of still higher amylose content is well under way as a result of the cooperative effort of chemists, plant breeders, and industry. Amylose is a linear polymer of glucose, whereas amylopectin, the other component of both high-amylose starch and ordinary corn starch, is a branched polymer of the same simple sugar. The molecules of amylose, being linear like those of cellulose, can form strong, flexible films and fibers, whereas amylopectin forms only very weak films. Because of its relatively high amylose content, high-amylose starch has inherent strength properties which make it potentially attractive for the development of new and improved starch-based industrial products including possibly coating adhesives. The potentialities for the development of new and improved coating adhesives from this new starch are discussed in the light of the known physical and chemical properties of its components, amylose and amylopectin. The results of preliminary studies on the oxidation, hydroxyethylation, and carboxymethylation of high-amylose starch and the effects of these modifications on its dispersibility and paste properties are presented.

THE potential utility of amylose as a raw material from which to make films, fibers, and other industrial products has been shown over the years in various studies on amylose prepared by fractionating starch. The properties of this linear molecular component of starch encouraged initiation at the Northern Laboratory in 1945 of a search for a natural source of starch that was richer in amylose than commercially available starches, most of which contain 20 to 30% amylose. This search, in cooperation with plant breeders, has led to the development of new varieties of corn yielding starch containing more than twice as much amylose as ordinary starches. Although the ultimate goal is the development of starch that contains 85% or more amylose, high yielding, commercial-type corn hybrids are now available which yield starch with 50 to 60% amylose. Since the properties of these starches are quite different from those of ordinary cornstarch, they may have advantages for certain uses including paper-coating applications. It appears worth while, therefore, to present some results obtained in the first studies on the new high-amylose starch and its derivatives and also to review briefly the collaborative work of plant breeders and chemists that has led to the present stage of development.

DEVELOPMENT OF HIGH-AMYLOSE CORN

Hundreds of samples of corn, wheat, sorghum, as well as other cereal grains and plant sources of starch were analyzed for the amylose content of their starches in the initial screening program at the Northern Laboratory. The most immediate result was the discovery of high-amylose starch in peas. Although starch containing as much as 60 to 70% amylose was found in various varieties of wrinkled-seeded peas, they were not an attractive source of amylose since they contained only about 45% starch together with a high amount of protein. The protein could not be separated effectively from the starch by any known means without adversely affecting starch properties. Major attention was then directed to cereal grains and in 1949 a corn supplied by the Bear Hybrid Corn Co., Decatur, Ill., was found to contain starch with 36% amylose instead of the usual 27%. The total starch content of this corn, in contrast to other high-amylose varieties which had been examined up to this time, appeared to be much the same as that found in field corn. Meanwhile in 1947, Cameron (*1*) working at Harvard with analyses supplied by Iowa State College, found that certain combinations of genes would give corn with starch of 65% amylose; the total starch content of this corn, however, was very low.

In 1950, the Northern Laboratory expanded its cooperative efforts to determine whether the desired type of corn might be produced by breeding. In cooperation with M. S. Zuber and associates of the Missouri Agricultural Experiment Station and USDA Crops Research Division, as well as with Bear Hybrid Corn Co., more than a thousand samples a year were analyzed for their amylose content over the next several years. Foreign varieties, inbred lines, and crosses produced by plant breeders were included in this study.

In 1952, Robert P. Bear (*2*) reported a gene (*ae*, for amylose extender) which increased the amylose content of corn in which it appeared. With this gene he bred a corn containing 60% starch of which 62% was amylose. This was the first high-amylose corn combining adequate starch content with sufficiently high level of amylose to be of industrial interest; its development was reported in 1954 (*3*) in a joint publication from the Northern Laboratory and the Bear Hybrid Corn Co. This amylose-extender gene (*ae*) was used during the next few years to develop a high-amylose corn having good agronomic characteristics and yielding, under normal conditions, up to 100 bushels per acre. Up to 60% of the corn on a dry basis is starch, the amylose content of which is between 50 and 60%. Seed produced by Bear Hybrid Corn Co. was used to grow high-amylose corn in Indiana under contract with two corn wet-milling companies. Approximately 10,000 bushels were harvested in the fall of 1958, and most of this has now been processed by the two participating companies.

Encouraged by the progress that had been made, the Northern Laboratory greatly increased its work with cooperating plant breeders. Between Dec. 26, 1956, and Oct. 1, 1957, about 8000 samples were analyzed for

F. R. SENTI and C. R. RUSSELL, Northern Regional Research Laboratory, Peoria, Ill. This is a laboratory of the Northern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

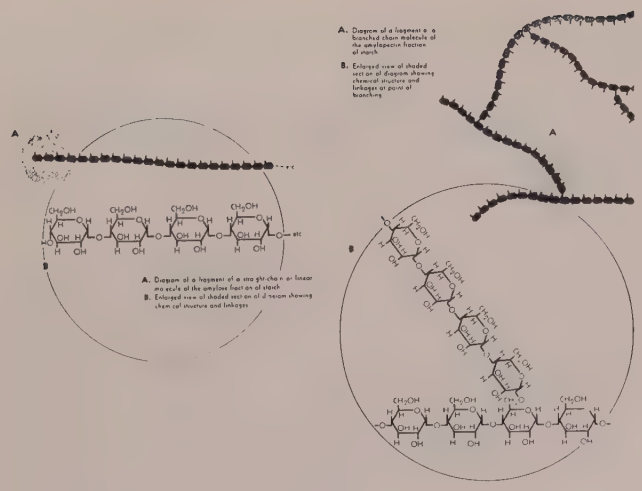

Fig. 1

amylose content. Since then, samples have been analyzed at a rate of 10,000 to 15,000 a year. This accelerated program enabled the breeders to make more rapid progress by eliminating unpromising material at earlier stages. It is now relatively common for workers at the Northern Laboratory to find starch that analyzes over 70% amylose in samples supplied by both cooperating plant breeders. In 1957, Dr. Zuber supplied a sample which, on the basis of our analysis, contained starch of over 80% amylose. Although only one sample this high in amylose has been received to date, attainment of a still higher content is confidently expected by both cooperating breeders. In the meantime, hybrid varieties with good agronomic properties are being developed which have amylose contents in a 60 to 80% range. Those having starch of 60 to 70% amylose are now well along genetically and, according to the corn breeders, could be available for commercial production within a few years. The price of such high-amylose starch can be expected eventually to be somewhere near that of ordinary starch when produced in reasonably large quantities. This prediction is based on analogy with another genetically special type of cornstarch already commercialized, namely, waxy maize starch which contains *only* amylopectin (i.e., no amylose).

This promise of success in the development of high-amylose corn encourages consideration of industrial utility of high-amylose starch. We are particularly interested in its possible use by the paper industry, since this is one of the largest industrial users of starch and starch products. The complete story on the applicability of high-amylose starch to papermaking and processing operations can only be gained through an extensive program of development-research and evaluation. This program has just begun and a limited amount of information is now available. Some further insight into both the potential advantages and the problems of using high-amylose starch can be gained by considering the properties of the two components of starch, amylose and amylopectin. Considerable basic information on these starch components is available, as well as some data on their application in papermaking. Knowledge of the properties of ordinary cornstarch, as well as its performance in various applications is also of much help in considering uses for high-amylose starch.

PROPERTIES OF AMYLOSE AND AMYLOPECTIN

Both amylose and amylopectin are polymers of the simple sugar glucose; but they differ in that amylose is a long, straight-chain polymer; whereas in amylopectin, branching occurs at frequent intervals. Marked differences in the physical properties of the two starch components are accounted for largely by these structural differences which are depicted in Fig. 1. The number of glucose residues joined to form a molecule of amylopectin or amylose varies with the plant origin of the starch. Amylose molecules from cornstarch contain about 1000 glucose residues on the average, whereas corn amylopectin is a much larger molecule and may contain 40,000 or more glucose residues. Although considerably smaller in size than amylopectin, amylose is a high molecular weight material comparable in size to many other natural and synthetic polymers finding industrial applications.

The solubility characteristics of amylose reflect the ability of its molecules to adopt different conformations in the solid state. Amylose molecules, for example, assume a helical form when precipitated from solution by butanol and other higher alcohols which form complexes with amylose. Amylose in this form will readily dissolve in hot water containing butanol. Amylose solutions of 10 to 20% concentration prepared from the amylose-butanol complex are stable above 60°C. even when the butanol is removed. The solutions quickly gel on cooling to about 60°C. and, when dried, the gel yields a tough coherent mass that is very difficult to redissolve in water even by autoclaving. Aqueous solutions of amylose at concentrations above 2% will gel when cooled to room temperature. More dilute solutions of amylose in water also are unstable at room temperature; they become turbid on standing due to the formation of molecular aggregates which gradually precipitate from solution. This precipitate, often referred to as *retrograded* amylose, will not dissolve in boiling water. Amylose molecules in the water-insoluble form are in an extended configuration that permits strong lateral interaction between adjacent molecules; it is these forces which restrict its solubility. In contrast to amylose, amylopectin is readily soluble in cold water, and concentrated solutions do not yield precipitates or gels on standing.

Amylose and amylopectin also differ widely in their film-forming properties. Grossly, the structure of amylose is similar to that of cellulose which after regeneration from an appropriate solution forms the well-known cellophane films. On the basis of structure one would presume that films of a similar type might also be formed from amylose. Indeed, this is the case as shown by work on the preparation and evaluation of amylose films (*4*). Except for wet strength, the mechanical properties of amylose films fall within the range of common plastic films. Dry, unoriented films have a tensile strength ranging from 9200 to 10,200 p.s.i., and an average elongation at break of 13%. Flexibility of unplasticized amylose films about 0.001 in. thick was good, ranging from 650 to 900 double folds before breaking on the Schopper endurance tester.

Results obtained by Wolff, *et al.* (*4*), at the Northern Laboratory on the properties of films cast from amylose and amylopectin mixed in various proportions are pertinent in our present consideration of high-amylose

Table I. Properties of Films from Mixtures of Corn Amylose and Corn Amylopectin[a] (50% R.H. and 72°F.)

Amylose content of film,[b] %	Haze, %	Tensile strength, kg. sq. mm. Dry	Tensile strength, kg. sq. mm. Wet	Ultimate elongation, % Dry	Ultimate elongation, % Wet	Schopper double folds, No.	Mullen burst points[c]	Elmendorf tear,[c] g.
95	14	7.1	0.15	23	18	960	22	6
86	13	5.5	0.13	8	13	530	15	5
77	13	6.0	0.20	11	16	450	13	7
68	22	6.2	0.14	15	14	350	18	7
59	27	6.4	0.16	10	19	140	17	7
50	26	6.0	0.14	6	17	100	15	6
42	36	4.9	0.07	6	11	63	12	5
29	11	5.1	0.05	6	11	28	10	6
24[d]	16	5.0	...	7	..	21	8	8
24	10	5.3	...	5	..	19	8	5
15	16	5.5	...	9	..	21	8	5
6	3	5.0	...	5	..	14	9	4

[a] Taken from I. A. Wolff, *et al., Ind. Eng. Chem.* 43: 915 (1951).
[b] Based on iodine affinities of amylose and amylopectin used and assuming that pure amylose sorbs 200 mg. of iodine per gram and amylopectin sorbs no iodine.
[c] Corrected to thickness of 0.025 mm. assuming direct proportionality.
[d] Unfractionated cornstarch in which granules had been disrupted by agitation of hot paste in Waring Blendor for 15 min.

starch. Data on films containing from 6 to 95% amylose show (Table I) that dry and wet tensile strengths, elongation, burst resistance, and flexibility are all decreased as the amylose content is lowered, indicating inherently poor mechanical properties for branched-chain amylopectin. Film flexibility appears to be particularly sensitive to amylopectin content; however, the results suggest that starch containing 80 to 85% amylose may have sufficiently good mechanical properties to make it useful as a raw material in the production of unsupported films.

PROPERTIES OF UNMODIFIED HIGH-AMYLOSE STARCHES

Most of our work thus far on high-amylose starch has been limited to starches with amylose content in the range 50 to 60%. Starches, separated from the grain by a wet-milling process (*5*) in laboratory and pilot-plant equipment, had a slightly higher protein content than commercial cornstarch; this may be related to the smaller granule size and more irregular granule shape of these particular high-amylose starches.

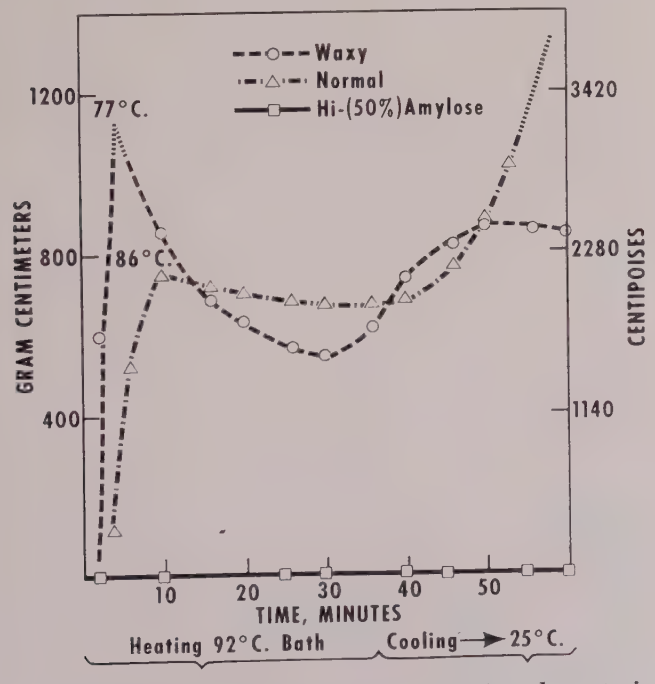

Fig. 2. Effect of amylose content on pasting characteristics of starch, determined by CIRF viscometer at 8 wt. % solids

From these high-amylose starches less amylose could be isolated by butanol fractionation than was determined by potentiometric iodine titration. Only 43% amylose was obtained after three recrystallizations from a starch that analyzed 54% amylose (*6*). This discrepancy was accounted for by the amylopectin fraction; it had higher iodine-binding capacity and also was less branched than ordinary-starch amylopectin. Similarly, starch containing 57% amylose by potentiometric titration has yielded about 48% by butanol fractionation. The molecular weight of the amylose was about the same as that from ordinary cornstarch, based on intrinsic viscosity measurements. Films cast from dispersions of high-amylose starch (50 to 60% amylose by titration) compare well in strength properties with those cast from a 50:50 mixture of ordinary corn amylose and amylopectin.

Granules of high-amylose starch swell much less at a given temperature in water than do granules of ordinary starch, for example, in boiling water high-amylose starch granules swell only slightly. This resistance to gelatinization is graphically demonstrated by comparing the viscosity time-temperature curves (Fig. 2) for high-amylose starch, amylopectin, and normal cornstarch when pasted in the usual manner in the Corn Industries Research Foundation viscometer at a bath temperature of 92°C. The absence of a measurable viscosity for high-amylose starch is a result of its failure to swell or gelatinize. The other two materials exhibit their usual behavior. Waxy maize starch, composed entirely of amylopectin, pasted very rapidly to a higher initial viscosity than normal starch, but fell off more rapidly with heating and stirring to give a somewhat lower hot-paste minimum. On cooling, normal starch set back more than the waxy starch, thereby reflecting the tendency of amylose in the normal starch to gel on cooling. If high-amylose starch is pasted by autoclaving at somewhat higher temperatures, the resulting paste shows a greater tendency to set up to a firm gel than a paste of normal starch at the same concentration.

It is evident that differences in behavior of normal and high-amylose starches are due to the increased amylose content of the high-amylose starch. Chemical modification of high-amylose starch obviously is necessary for applications requiring ease of pasting and stability of dispersions.

RELATION OF STARCH COMPONENTS AND MODIFICATIONS TO ADHESIVE PROPERTIES

The properties required for coating adhesives are discussed in detail in a series of articles in *Tappi* covering papers presented at the Third Coating Conference in 1952 (*7*) and in TAPPI Monograph No. 17 (*8*) published in 1957. Reference to some of the more pertinent points brought out in these sources will be made in order to obtain a better understanding of the potential utility of high-amylose starch modifications as coating adhesives.

Even normal cornstarch, containing about 27% amylose, requires modification to meet the requirements of a coating adhesive. Pastes of the unmodified starch have too great a tendency to gel and impart too high a viscosity when used in sufficient amount to provide the necessary strength. Gel formation is directly attributable to the amylose. High paste viscosity results primarily from two factors: one is the high molecular weight of the starch components, and the other is the presence of relatively intact, greatly swollen granules or large fragments thereof. To overcome the disadvantages of gelation and high viscosity, several methods of starch modification can be used, including acid and enzymic hydrolysis, dextrinization, oxidation, and derivatization (e.g., hydroxyethylation). A brief consideration of the changes brought about in normal starch and its components by these treatments will provide a background in discussing the results of our studies thus far on modifying high-amylose starch.

Gel formation by amylose, and the related phenomenon of retrogradation from solution, results from the linearity of amylose molecules and their ability to associate through hydrogen bonding or related forces The tendency to gel can be reduced by decreasing molecular size or by introducing inhomogeneity in the linear structure, either as branching or as scattered substituent groups, such as hydroxyethyl groups.

Hydrolysis by acid or by alpha-amylase modifies starch properties by reducing the molecular size of both amylose and amylopectin. Separate studies on amylose itself have shown, according to Schoch (*9*), that ability to form a gel is destroyed by cleaving each molecule only two or three times. However, the product at this stage has an increased tendency to retrograde or form an insoluble precipitate, probably because of greater mobility and ease of orientation of the shorter linear molecules. This tendency to retrograde is progressively reduced as the molecule is further hydrolyzed; but desirable properties which are dependent on molecular size, such as the ability to form strong flexible films and to provide emulsifying and protective colloid action, are also progressively lowered. If whole starch is hydrolyzed in this manner, the branched fraction is also attacked; and by the time the linear fraction is sufficiently reduced in size to prevent its retrogradation, the starch has little useful adhesive properties.

Dextrinization at relatively moderate temperatures and for short periods of time, as employed in the preparation of white dextrins, is also mainly a hydrolytic conversion and leads to results similar to those obtained by hydrolysis. When dextrinization is carried out at somewhat higher temperatures for longer periods of time, the hydrolysis is accompanied by a repolymerization of the fragments into branched molecules. Thus, the amylose or original linear fraction is changed to a branched molecule and the amylopectin is converted into a more highly branched product. Introducing branching into the amylose structure prevents gel formation and retrogradation. However in the case of normal starch, dextrinizing to this extent tends to destroy desirable properties, such as film strength, flexibility, and adhesiveness, probably as a result of both molecular breakdown and the increased branching in the amylopectin component. In view of these considerations dextrinization of high-amylose starch has not been included in our first series of modifications. Dextrinization merits later investigation since a starch having very high-amylose content could yield a dextrin composed essentially of only slightly branched molecules. Such a product might have favorable properties for coating or other applications.

Oxidation appears to be the most satisfactory method to modify normal starch for coating applications. Derivatization, also, is becoming of greater interest. In both cases, amylose gelation or retrogradation is prevented by the introduction of heterogeneity in the molecule in the form of randomly distributed oxidized or substituted glucose units. In addition viscosity can be reduced as needed by limited degradation. Advantages for the modification of high-amylose starch by oxidation and by derivatization, therefore, exist in the possibility of relatively independent variation in heterogeneity (degree of substitution) and molecular size.

The applicability of essentially linear molecular products as coating adhesives is indicated, for example, by experiments reported by Kerr (*10*) with amylose and amylopectin fractions of starch. Amylose in clay coatings had a higher adhesive strength than amylopectin at equal concentrations. Viscosities of both undegraded fractions were too high for application at concentrations required to give a coated paper suitable for printing. The amylose-containing mixtures were applied at 75°C. to prevent retrogradation and gelling. Thus both advantages and disadvantages of molecular linearity are shown in these experiments. The problem of viscosity is related partially to adhesiveness. An increase in adhesive-strength would permit use of lower concentrations of a product which otherwise would give mixtures of too high viscosity. Such enhanced adhesive qualities are claimed for polyvinyl alcohol (*11*): Good results can be obtained with as little as 2 to 5 parts of this polymer to 100 parts of clay. Certain grades of polyvinyl alcohol devoid of all acetate side chains tend to form a gel structure on standing; but when only a very small amount of acetate groups are present, this tendency is eliminated, again demonstrating the important effect of partial derivatization and resulting structural heterogeneity.

MODIFICATION OF HIGH-AMYLOSE STARCH PROPERTIES

Preliminary studies have been made at the Northern Laboratory to determine the effect of hypochlorite oxidation, hydroxyethylation, and carboxymethylation on the properties of high-amylose (50% by iodine titration) starch. Hypochlorite oxidation was carried out in aqueous starch slurries at alkaline pH near room temperature according to a previously described procedure (*12*). Hydroxyethylation by the method of Rankin,

Table II. Effects of Hydroxyethylation on Properties of High(50%)-Amylose Corn, Normal Corn, and Waxy Maize Starches

Hydroxyethylated starch	Wt., % HE[a]	Solids in paste wt., %	Paste pH	Viscosity in cp.[b] Hot max.	Hot min. 90°C.	55°C.	25°C.	Clarity 1% paste
High-amylose	7	8	7.0	63	54	191	440	29
High-amylose	12	8	7.0	140	77	177	630	40
Normal corn	7	8	7.0	860	860	1130	1760	69
Normal corn	12	8	7.0	1100	905	2290	2540	70
Waxy maize	7	8	7.0	2240	1750	2280	3200	80

[a] HE = hydroxyethyl.
[b] Paste viscosities determined in the Corn Industries Research Foundation viscometer.

et al. (*13*), essentially consisted of adding an appropriate amount of ethylene oxide to starch containing from 10 to 15% moisture and a small amount of alkaline catalyst while the reaction mixture was kneaded in a closed reaction vessel. Carboxymethylation with chloroacetic acid and alkali was carried out on starch suspended in ethanol containing approximately 5% moisture at reflux temperature essentially according to the method of Filbert (*14*).

Pasting characteristics of modified high-amylose starches were determined in either a CIRF viscometer or a Brabender Amylograph viscograph. In using the Amylograph, aqueous slurries were heated from 25°C. up to 90°C. at a rate of 1.5°C. per min., held at 90°C. for 17 min., then cooled at the same rate to 25°C.; changes in viscosity were recorded throughout the entire cooking cycle. The rate of stirring was 75 r.p.m. For the CIRF viscometer the stirring rate was 60 r.p.m. and the holding time of the paste was 30 min. at or near 90°C., except for the oxidized starches which were held for 45 min. at 90°C. and then allowed to cool to room temperature.

Paste clarities were determined in a spectrophotometer at 650 μ using distilled water as the standard for 100% transmission. Setback viscosities were determined on the aged pastes with a Brookfield viscometer.

The comparative effect of hydroxyethylation on the properties of high-amylose cornstarch, ordinary cornstarch, and waxy maize starch are given in Table II. In high-amylose starch approximately 5 to 7% hydroxyethyl groups were required to give a stable paste. Lesser amounts stabilize ordinary starch pastes, and no modification is needed to obtain stability with waxy maize starch (amylopectin). So that a better comparison could be made, all starches were modified to the same extent. After hydroxyethylation, high-amylose starch gave much less viscous pastes than the other two starches. Lower clarity of high-amylose derivatives indicates less complete dispersion, but still represents a marked improvement over unmodified high-amylose starch. Despite their lack of clarity, hydroxyethylated high-amylose starch pastes showed no tendency to gel or precipitate out on standing at room temperature for several days. At the end of one week setback viscosities, not shown, were not significantly different from the values obtained at 25°C. on completion of the cooking-cooling cycle. As far as applicability to coating is concerned, the improved dispersibility and paste stability achieved by hydroxyethylating high-amylose starch are certainly changes in the right direction. Evaluation trials in paper coating are needed to determine whether the viscosity still shown can be compensated by lower concentrations in the coating mixture. If not, it seems probable that derivatives can be prepared with viscosities reduced to satisfactory levels without excessive reduction in chain length and without major loss of strength properties inherent in the amylose fraction.

Table III. Effect of Hypochlorite Oxidation on Properties of High(50%)-Amylose and Normal Cornstarches

Oxidized starch	Oxidation[a] %	Solids in paste wt., %	Paste pH	Viscosity in cp.[b] Hot max.	Hot min. 90°C.	25°C.	Setback[c]	Clarity 1% paste
High-amylose	3.6	5	5.8	0	0	42.5	42.5	63.3
	3.6	8	5.8	23	0	269	231	
	3.6	11	5.8	537	114	1650	2840	
	6.0	5	5.9	0	0	16.0	18.5	90.2
	6.0	8	5.9	0	0	53	84	
	6.0	11	5.9	203	0	339	1502	
	9.8	5	5.5	0	0	8.5	8.5	96.5
	9.8	8	5.5	0	0	15.6	12.5	
Normal corn	3.0	5	5.1	637	0	...	...	...
	4.3	5	5.3	354	0	...	...	...
Commercial oxidized starch		16	6.0	66	33	198	...	...
		20	6.0	157	58	479	...	...

[a] Moles of carboxyl plus carbonyl groups per 100 anhydroglucose units.
[b] Determined in a Corn Industries Research Foundation viscometer, except for the commercial oxidized starch which was measured with a Brabender Amylograph viscograph.
[c] Measured with a Brookfield viscometer after standing for one week or more at room temperature.

Results on high-amylose starch and normal cornstarch with hypochlorite oxidation are compared in Table III. The lowest level of oxidation that can be employed with high-amylose starch, and still obtain a product yielding a relatively stable paste, is about 6% or 6 moles of carboxyl and carbonyl groups per 100 anhydroglucose units. In contrast, nongelling pastes

Table IV. Effect of Carboxymethylation on Properties of High(50%)-Amylose Starch Sodium Salt of Carboxymethyl Derivatives, pH 11 After Pasting

DS[a]	Solids in paste wt., %	Viscosity in cp.[b] Hot min. 90°C.	55°C.	25°C.	Setback[c]
0.11	5	190	239	478	Slight
0.11	10	676	1023	>1650	...
0.44	5	74	99	157	None
0.44	10	173	346	594	None
0.91	5	107	165	289	None
0.91	10	363	594	1089	None

[a] DS = average number of carboxymethyl groups per anhydroglucose unit.
[b] Paste viscosities determined in a Brabender Amylograph viscograph.
[c] Determined after one week of standing at room temperature.

Table V. Comparative Effects of Carboxymethylation on the Properties of Amylose, High(50%)-Amylose Starch, Normal Cornstarch, and Cellulose

	DS[a]	Solids in paste wt., %	Paste pH	Viscosity in cp.[b] Hot min. 90°C.	55°C.	25°C.
Carboxymethylated amylose	0.80	2	7	15	17	23
Carboxymethylated high-amylose starch	0.91	2	7	31	33	38
Carboxymethylated normal cornstarch	0.80	2	7	317	404	569
Carboxymethylated cellulose	0.70	2	7	282	627	1270

[a] DS = average number of carboxymethyl groups per anhydroglucose unit.
[b] Paste viscosities determined in a Brabender Amylograph viscograph.

can be made with normal cornstarch at lower levels of oxidation. Although pastes of high-amylose starch at the 3.6 and 6.0% levels of oxidation showed little setback except at a concentration of 11%, all the pastes tended to settle out slowly at room temperature. At the end of 48 hr. this settling effect in 5% pastes at the 3.6 oxidation level was quite noticeable; it was not so pronounced at the 6% oxidation level, but still perceptible. At the 9.8% oxidation level high-amylose starch gave very clear nonsettling pastes which exhibited no setback. Viscosity at 25°C., setback, and clarity were not determined on the oxidized normal corn starch samples; these were quite clear and fluid after the cook. The possible suitability of oxidized high-amylose starch for coating applications is evident from the viscosity, clarity, and nonsettling nature of the pastes at the 9.8% level of oxidation. Again, actual tests of these and similar products in coatings are required to determine what further modifications, if any, are needed.

Data on carboxymethylated high-amylose starch are given in Table IV. The lowest degree of substitution (DS) shown is 0.11, which is just below that required to give a cold water-soluble sodium salt. This product, however, readily dissolves in water at about 50°C. at a pH of 11.0. Since the carboxymethylated starches were all soluble in water at room temperature or slightly above, they exhibited no hot maximum on pasting. All carboxymethyl high-amylose starches gave quite clear pastes which showed no tendency to form precipitates at concentrations up to 10%. No setback on standing at room temperature was observed except for the product of DS 0.11. Its 5%-paste showed some thickening but still poured readily, while its 10%-paste gave a gel which would not pour. In the middle range of substitution, DS 0.44, viscosities tended to be lower than at either extreme of substitution.

Properties of carboxymethyl derivatives of high-amylose starch, amylose, ordinary cornstarch, and cellulose all at approximately the same DS are compared in Table V. These products were obtained from the sodium salt, which contained some excess sodium hydroxide, by dialysis against distilled water. Total solids in the solutions after dialysis were determined, and their volumes were adjusted to give the 2% solutions or suspensions used in the pasting studies. The pH readings of 7.0 on 2% pastes after cooking in distilled water indicated that the derivatives were in the partial salt form. At equivalent concentrations carboxymethyl amylose gave the lowest viscosity and was followed, in order of increasing viscosity, by carboxymethyl high-amylose starch, carboxymethyl ordinary starch, and carboxymethyl cellulose. The carboxymethyl derivatives of high-amylose starch have relatively low viscosities and, therefore, like the hydroxyethylated products have enhanced opportunity for being converted into effective coating adhesives.

EVALUATION OF MODIFIED HIGH-AMYLOSE STARCH

Oxidized high-amylose starches are currently being tested as a coating adhesive; however, no results are as yet available. Studies also are in progress on methods for reducing the viscosities of the other high-amylose starch derivatives to more appropriate levels. It is hoped that this can be accomplished with limited degradation of the derivatized amylose, not only to retain the strength properties that are inherent in this component, but also to obtain the beneficial effects that are attributed to the linear component such as imparting thixotropy to the coating color and providing a better opportunity for cross-linking which is needed to improve wet-rub resistance. Linear molecules can align parallel to one another better than branched molecules and where this situation exists, cross-linking reagents should function more effectively. Any products we obtain within range of the required viscosity for coating adhesives will be evaluated. The possibility remains, as already noted, that higher viscosities at a given concentration may be permissible with modified high-amylose starch because derivatized amylose may have enhanced binding power and thus could be used in lesser amounts.

Other applications of high-amylose starch products in the paper field also are being considered. Analogous water-soluble cellulose derivatives, in general, are effective as internal and external sizing agents and are used to improve strength, printability, and resistance to grease, oils, solvents, and abrasion. In sizing, viscosity is not such a limiting factor as in coatings. In beater additives, high viscosity is desirable. Plans have been made to evaluate hydroxyethylated and carboxymethylated high-amylose starches, as well as other derivatives when they become available, in these applications.

Research and development on high-amylose starches are being carried forward as fast as available resources permit. Only in this way can the ultimate place of high-amylose starches in papermaking and other industrial applications be determined.

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The Effect of pH on Pulp Degradation in Each Hypochlorite Stage of a Six Stage Sulfate Pine Bleaching System

M. G. LYON and A. C. SALISBURY

Data are presented to show that the effects of pH in the successive hypochlorite stages of a multistage bleaching system of southern pine sulfate pulp are similar but not identical. The hypochlorite stages of a chlorine-hypochlorite - caustic - hypochlorite - caustic - hypochlorite bleaching sequence were carried out at pH's from 10 to 1.5, ± 0.2 pH. The pulps were tested for viscosity, brightness, permanganate number, brightness loss on oven fading, and hot alkali solubility. Data show pH effect on viscosity in stage 2 differs from stages 4 and 6. Also the effect on brightness, hot alkali solubility, and permanganate number differed in some respects in stage 2 from stages 4 and 6. Temperature of 110°F. versus 145°F. had only slight effect except on rate of bleach consumption, and to a lesser degree on brightness. The necessity is indicated for keeping the pH in all hypochlorite bleaching stages above 8 for optimum bleaching results.

HISTORICAL

The effect of pH on the action of hypochlorite on cellulose during oxidation or bleaching has been the subject of numerous investigations covering many years. It is generally conceded that proper control of hypochlorite pH is a most important matter in pulp bleaching.

Clibbens and Ridge (*1*), in a study of the action of hypochlorite on cotton cellulose, showed that severe degradation occurred at pH of 7, and pH's of 9 to 13 must be maintained to lessen the cellulose degradation. Rapson, in 1955 (*2*), reported a fine and extensive study on the role of pH in bleaching pulp with various bleaching agents. His work also showed a sharp viscosity drop in the neutral pH range when bleaching sulfite and sulfate pulps with chlorine. He reported generally optimum brightness levels secured at pH range of 7 to 11. Giertz (*3*) reports that hypochlorite oxidation of cellulose under highly alkaline conditions leads to the formation of fairly stable carboxyl groups, while carbonyl groups are formed at lowered pH levels. Similarly Rapson, Anderson, and King (*4*) on cotton linters and sulfite pulp found that bleaching at pH 7 caused an increase in carbonyl groups and an increase in color reversion tendencies compared with bleaches at pH 10.

Not only does low bleaching pH cause increased cellulose degradation, but the stability of the hypochlorite solution is lowered at pH's below 11.2 as indicated by O'Neil and Rue (*5*). Parsons (*6*) reported that below pH 7.5 a portion of the hypochlorous acid present in a bleaching stage may be lost through volatilization and decomposition so that bleaching efficiencies are reduced.

While many separate studies have detailed the effect of bleaching stage pH on pulp degradation, brightness and color stability, little work has been done to investigate fully the importance of pH to the course of the reaction in each of the hypochlorite stages of a typical multistage sulfate bleaching system. In operating a six-stage bleaching system on southern pine sulfate pulp the Champion Paper & Fibre Co. has noticed that there appeared to be a difference in the way pH influenced the degradation pattern between fairly well purified pulp and the less purified pulp of the earliest hypochlorite stage. The six-stage bleaching sequence employed consisted of: chlorination, hypochlorite, alkaline extraction, hypochlorite, alkaline extraction, and final hypochlorite. Investigations had indicated that pulp in the first hypochlorite stage was subject to increasing degradation with lowered pH down to pH 3 rather than having greatest degradation at near the neutral point as indicated by the published literature on the subject.

The apparent discrepancy between our test results and the published literature prompted this extensive study of the role of pH in each of the three hypochlorite stages. The role played by pH in each bleaching stage has been studied and indicated by tests of pulp viscosity, brightness, brightness stability, alkali solubility, permanganate number, and time for bleach exhaustion.

EXPERIMENTAL

Pulp.—The pulp used for these bleachings was southern pine sulfate pulp having a cupriethylene-

M. G. Lyon, Director of Pulp Manufacturing, and A. C. Salisbury, Associate Research Engineer, The Champion Paper and Fibre Co., Hamilton, Ohio.

Table I. Bleaching Data and Test Results for Stage 2

Bleach S-238	Regular composite	Stage 2																	
		110°F.									145°F.								
Sequence →	C	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Stage →	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Sample no. →	..	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Chemical applied, %	5.60	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Chemical consumed, %	5.58	3.47	3.5–	3.49	3.49	3.49	3.49	3.5–	3.49	3.48	3.49	3.5–	3.5–	3.5–	3.5–	3.5–	3.5–	3.5–	3.5–
Consistency, % o.d.[a]	3.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Bleaching time, min.	45	60	50	55	55	70	65	95	90	95	30	25	20	15	15	20	20	25	30
Bleaching temp., °F.	80	110	110	110	110	110	110	110	110	110	145	145	145	145	145	145	145	145	145
Buffer (% NaOH)	...	(pH controlled within ±0.2 by adding acid or base as needed)																	
pH at start	1.7	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	1.5	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	1.5
pH at end	1.6	10.1	9.15	8.0	7.2	6.2	4.8	3.9	2.8	1.5	10.0	8.9	7.8	7.2	6.2	4.8	4.2	3.1	1.5
G.E. brightness	(27)	58.3	62.5	60.0	59.3	57.0	53.8	52.3	47.5	46.6	55.3	56.5	56.7	57.7	54.6	53.7	52.2	45.3	45.2
Faded brightness	...	55.0	58.1	55.7	53.0	50.7	47.1	46.6	41.2	40.6	53.7	53.4	52.3	52.9	49.3	47.2	47.4	41.2	39.9
Brightness lost	...	3.3	4.4	4.3	6.3	6.3	6.7	5.7	6.3	6.0	1.6	3.1	4.4	4.8	5.3	6.5	4.8	4.1	4.3
Viscosity, cp.	22.8	18.9	16.9	16.3	12.4	8.8	6.0	6.2	5.3	12.5	18.3	17.8	13.7	10.7	8.3	6.7	6.9	5.8	5.9
$KMnO_4$ no.	7.2	1.9	1.5	1.4	1.5	1.4	2.0	1.9	2.5	2.6	2.1	1.6	1.5	1.4	1.7	1.7	2.1	2.4	2.9
Alkali solubility, (7.14% NaOH	14.34	13.31	13.67	15.10	18.97	24.56	30.61	29.76	25.66	15.09	9.94	12.82	16.52	19.92	22.72	26.33	26.27	33.41	30.11

[a] o.d. = ovendry.

Table II. Bleaching Data and Test Results for Stage 4

Bleach S-239	Preliminary regular stages			Stage 4															
				110°F.									145°F.						
Sequence →	C	B	N	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Stage →	1	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Sample no. →	..	..	..	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Chemical applied, %	5.60	3.50	1.75	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60–
Chemical consumed, %	5.54	3.48	...	0.59	0.59	0.59	0.60–	0.60–	0.60–	0.60–	0.59	0.60–	0.59	0.59	0.60–	0.60–	0.60–	0.60–	0.60–	0.60–	0.60
Consistency, % o.d.[a]	3.0	3.5	10.	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Bleaching time, min.	45	50	45	243	285	213	158	120	103	106	106	93	65	45	35	31	23	37	43	52	60
Bleaching temp., °F.	78	110	140	110	110	110	110	110	110	110	110	110	145	145	145	145	145	145	145	145	145
Buffer, % NaOH	...	2.4	...	(pH controlled within ±0.2 pH by adding acid or base as needed)																	
pH at start	2.0	10.3	...	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	1.5	10.0	9.1	8.0	7.0	6.0	5.0	4.0	3.1	1.5
pH at end	2.1	9.0	11.8	9.8	8.8	8.0	7.2	6.2	4.8	3.9	2.9	1.5	9.8	9.1	8.1	7.0	6.2	5.2	4.0	2.9	1.4
G.E. brightness	26.2	55.7	57.0	74.2	76.9	77.2	75.6	74.0	72.1	72.0	70.9	69.7	78.8	76.3	77.7	75.2	74.5	74.6	76.1	75.5	75.7
Faded brightness	24.7	51.6	54.4	70.0	72.0	71.6	70.1	68.5	66.5	65.7	64.6	63.9	73.7	71.4	71.9	68.9	68.1	68.1	68.4	68.4	67.9
Brightness lost	1.5	4.1	2.6	4.2	4.9	5.6	5.5	5.5	5.6	6.3	6.3	5.8	5.1	4.9	5.8	6.3	6.4	6.5	7.7	7.1	7.8
Viscosity, cp.	22.0	21.1	21.7	17.8	15.9	14.1	11.0	9.1	9.5	13.7	13.6	17.8	15.5	15.1	12.8	8.4	8.8	10.0	11.4	16.0	17.2
$KMnO_4$ no.	9.2	2.6	2.05	1.1	0.95	1.05	0 95	0.95	0.90	0.95	0.85	0.80	1.05	1.05	0.95	0.90	0.85	1.00	0.80	0.70	0.80
Alkali solubility, (7.14% NaOH)	...	...	...	13.84	12.00	13.94	17.57	19.26	17.20	14.40	13.78	11.02	11.67	13.47	15.64	21.29	20.58	17.44	13.88	12.24	11.83

[a] o.d. = ovendry.

Table III. Bleaching Data and Test Results for Stage 6 (0.3% Cl)

Bleach S-238	Preliminary regular stages					Stage 6, 110°F.									Stage 6, 145°F.									
Sequence →	C	B	N	B	N	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Stage →	1	2	3	4	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Sample no. →	..	..	..	..		1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	
Chemical applied, %	5.60	3.50	1.75	0 60	1.25	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	
Chemical consumed, %	5.58	3.45	...	0.53	...	0.16	0.25	0.27	0.28	0.30–	0.23	0.28	0.29	0.29	0.28	0.23	0.29	0.30–	0.30–	0.30–	0.30–	0.30–	0.30–	
Consistency, % o.d.[a]	3.0	3.5	10	10	10	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	
Bleaching time, min.	45	85	45	210	45	150	255	260	180	160	97	113	100	157	48	41	58	40	50	50	30	77	60	
Bleaching temp., °F.	80	108	140	110	140	110	110	110	110	110	110	110	110	110	145	145	145	145	145	145	145	145	145	
Buffer, % NaOH	...	2.4	...	0.28	...	(pH controlled within ±0.2 by adding acid or base as needed)																		
pH at start	1.7	10.3	...	10.4	. .	10.2	9.2	8.0	7.2	6.0	5.2	4.0	3.0	1.5	10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	1.5	
pH at end	1.6	8.6	11.6	8.6	11.6	9.8	8.9	7.8	6.8	5.8	5.0	4.2	3.0	1.5	10.2	8.9	8.0	7.1	5.9	4.8	4.0	2.8	1.5	
G.E. brightness	(27)	60.3	61.8	76.3	75.1	79.8	80.0	80.0	80.6	81.9	81.6	81.3	80.9	81.4	80.4	80.0	79.7	80.3	82.2	82.8	82.3	83.3	83.7	
Faded brightness	...	57.2	59.9	70.9	71.7	75.0	75.3	74.8	74.5	73.9	74.6	74.3	74.2	75.0	76.6	76.1	75.8	75.9	76.4	76.7	76.8	77.0	76.8	
Brightness lost	...	3.1	1.9	5.4	3.4	4.8	4.7	5.2	6.1	8.0	7.0	7.0	6.7	6.4	3.8	3.9	3.9	4.4	5.8	6.1	5.5	6.3	6.9	
Viscosity, cp.	22.8	18.4	17.4	12.9	12.3	11.4	10.7	10.3	9.0	8.1	10.5	11.2	11.2	11.9	11.5	11.6	10.9	9.8	9.6	9.6	12.0	12.0	12.5	
$KMnO_4$ no.	7.2	1.99	1.45	1.1	1.07	...	0.88	...	...	...	...	...	...	...	...	0.90	...	...	...	...	...	...	...	
Alkali solubility, (7.14% NaOH)	14.34	...	..	..	...	13.38	13.77	15.69	14.78	13.69	12.97	12.28	10.61	10.66	12.66	12.81	12.79	14.19	15.85	16.10	12.68	11.00	.12.69	

[a] o.d. = ovendry.

Table IV. Bleaching Data and Test Results for Stage 6 (1.0% Cl)

Bleach S-240	Preliminary regular stages					Stage 6																
						110°F.												145°F.				
Sequence →	C	B	N	B	N	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Stage →	1	2	3	4	5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Sample no. →	..	..	..	..	..	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Chemical applied, %	5.60	3.50	1.75	0.57	1.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chemical consumed, %	5.56	3.48	...	0.47	...	0.56	0.58	0.82	0.98	0.99	0.99	0.99	0.98	0.98	0.97	0.99	1.0–	1.0–	1.0–	1.0–	1.0–	0.99	0.99
Consistency, % o.d.[a]	3.0	3.5	10.0	10.0	10.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Bleaching time, min.	80	76	45	200	45	452	435	413	355	203	230	290	450	475	192	118	67	39	50	73	85	125	156
Bleaching temp., °F.	82	110	140	110	140	110	110	110	110	110	110	110	110	110	145	145	145	145	145	145	145	145	145
															(pH controlled within ±0.2 by adding acid or base as needed)								
Buffer, % NaOH	...	2.4	...	0.27	...	...	...	8.1	7.1	6.2	5.1	4.0	3.0	1.5	10.0	9.0	8.0	7.1	6.0	5.0	4.0	3.0	1.5
pH at start	1.7	10.5	...	10.7	...	10.0	9.0	8.1	7.2	6.0	5.0	4.2	3.0	1.5	10.0	8.8	8.0	7.1	6.2	5.2	4.2	2.8	1.5
pH at end	1.6	9.3	11.5	9.7	11.2	10.1	9.0	8.1	7.2	6.0	5.0	4.2	3.0	1.5	85.1	84.3	82.4	82.3	82.2	82.6	83.5	83.6	84.1
G.E. brightness	28.5	61.1	62.7	75.9	75.8	75.9	81.7	82.5	81.2	81.4	81.8	80.7	80.2	80.1	79.5	78.7	75.3	71.0	71.4	73.4	72.7	73.5	75.9
Faded brightness	26.3	57.3	60.0	70.4	71.5	76.7	78.2	78.8	77.2	76.9	76.9	76.3	74.0	73.5	79.5	78.7	75.3	71.0	71.4	73.4	72.7	73.5	75.9
Brightness lost	2.2	3.8	2.7	5.5	4.3	3.2	3.5	3.7	4.0	4.5	4.9	4.4	6.2	6.6	5.6	5.6	7.1	11.3	10.8	9.2	10.8	10.1	8.2
Viscosity, cp.	19.6	16.6	15.8	12.7	12.9	8.8	8.9	8.1	5.7	5.0	5.9	5.7	6.8	7.4	7.4	6.9	6.6	5.1	4.7	6.2	6.3	6.8	9.1
$KMnO_4$ no.	8.35	1.90	1.46	1.18	1.05	0.65	...	...	...	...	...	...	...	...	0.70	...	...	...	...	...	...	...	...
Alkali solubility, % (7.14% NaOH)	19.75	12.64	12.68	12.68	12.58	12.62	14.56	16.55	20.94	26.89	26.41	21.26	20.63	21.14	16.23	19.06	22.88	29.55	29.51	27.28	24.53	20.02	14.73

[a] o.d. = ovendry.

diamine viscosity of 32.0 cp. and 20.0 cc. TAPPI permanganate number.

Bleaching Procedure. This pulp, as stated above, was bleached by a six-stage, chlorine-hypochlorite-caustic - hypochlorite - caustic - hypochlorite sequence. The pulp for the stage 2 (first hypochlorite)bleachings was first chlorinated and washed in the usual manner. Portions of this pulp were bleached to virtual exhaustion of the applied bleach, at pH's ranging respectively from 10 to 1.5. These values were maintained throughout the bleach within ±0.2 pH by adding NaOH or H_2SO_4, as needed. The bleachings were done at 110°F. and at 145°F. Bleaching conditions, viscosity, applied and consumed available chlorine, etc., are given in Table I.

Similarly, the pulp for the stage 4 (second hypochlorite) bleachings was carried through the first three bleaching stages, using normal conditions, then treated in the same manner as the stage 2 bleaches. The bleaching data are given in Table II.

For the stage 6 (third hypochlorite) bleachings, the pulp was taken through five stages using normal conditions, then bleached in a manner similar to stages 2 and 4, except that the full series of bleachings was made at two levels of applied available chlorine, the normal 0.3% based on ovendry pulp weight, and 1.0% bleaching data are given in Tables III and IV.

Available Chlorine Applied. The amount of available chlorine applied in the different stages, as shown in Tables I, II and III, was that applied as standard practice in routine laboratory bleachings of pulps in the

Fig. 1. Viscosity versus pH

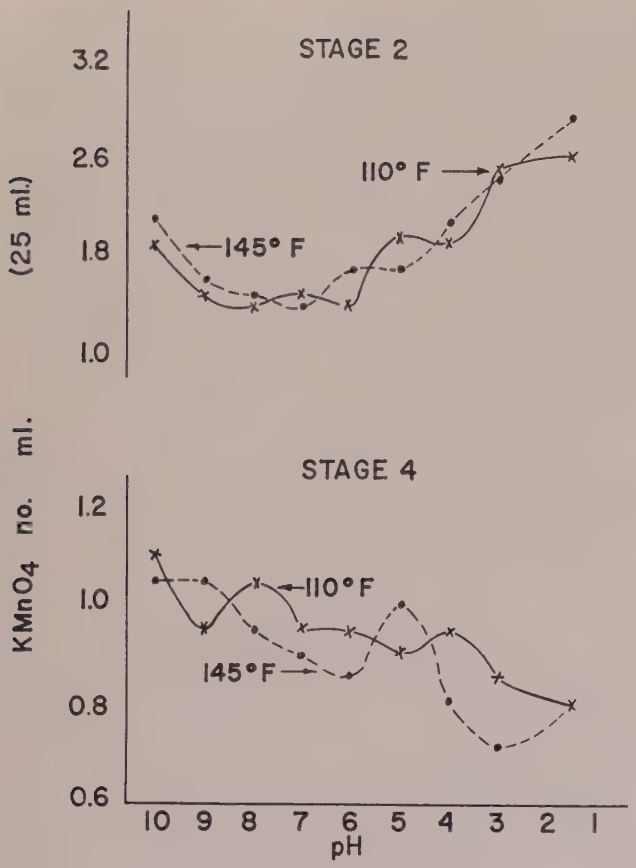

Fig. 2. $KMnO_4$ no. versus pH

same permanganate number range as the pulp used for these bleachings.

An excessive amount of bleach (Table IV) was applied in the second series of stage 6 bleaches to check whether the differences noted in the stage 2 bleaches might be due to the larger amount of bleach (available chlorine) applied in the second stage.

The pulps, after bleaching and washing with ten parts of water to one of pulp, were formed into sheets using a Noble & Wood sheet mold and press. Brightness sheets were formed in distilled water and dried on the Noble & Wood drier at 250°F. for approximately 3 min.

The pulp sheets used for the remainder of the tests were airdried after pressing.

Tests. The pulps, for each stage investigated, were tested for viscosity, brightness before and after oven fading, permanganate number and solubility in hot, 7.14% NaOH solution.

The viscosity was determined in 0.5% concentration in cupriethylenediamine solution according to TAPPI Standard T 230 sm-50.

Brightness was read with a G.E. brightness tester. The oven-faded sheets were heated for 4 hr. at 105°C. in a forced circulation oven.

Permanganate number was determined by TAPPI Standard T 214 m-50, using 25 ml. of standard permanganate solution.

Alkali solubility was determined by treating 1 g. of ovendry pulp for 3 hr. at 99° to 100°C. in 100 ml. of 7.14% NaOH solution. The treated pulp was neutralized with 20 ml. of glacial acetic acid. The washed residue was dried to constant weight at 105°C. and the per cent loss in weight determined.

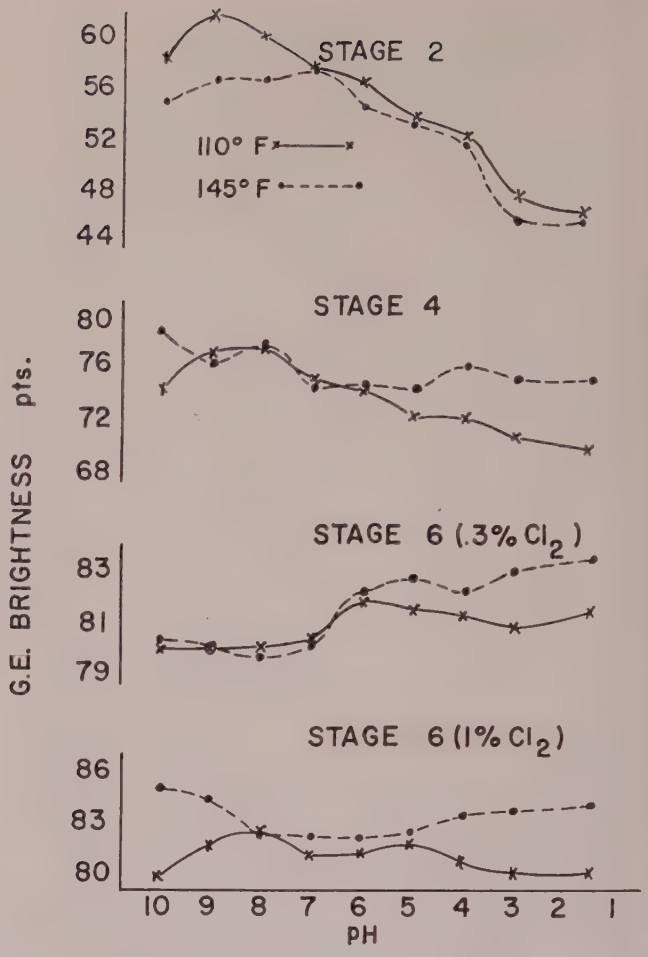

Fig. 3. G.E. brightness versus pH

Results. The results of the above tests are given in Tables I through IV.

DISCUSSION

Viscosity

In evaluating what happens to pulp viscosity in a hypochlorite stage, as it is carried out at progressively lower pH's, it is evident (Fig. 1) that the effect is similar but not identical in the successive bleaching stages.

In stage 2, with a viscosity of 22.8 cp. (Table I) entering the stage, the viscosity at the end of the stage was 18 to 19 cp. for a pH of 10. The viscosity dropped with decreasing pH to 5 to 6 cp. at a pH of 3, then rose sharply to 12.5 cp. at a pH of 1.5 for the bleach at 110°F. It merely leveled off at a pH of 1.5 in the 145°F. bleach.

In stage 4, the viscosity entering the stage was 21.7 cp. (Table II). At the end of the stage, for a pH of 10 and 110°F., the viscosity was 17.8 cp. It passed through a minimum of 9.1 cp. at pH 6, then increased to 17.8 cp. at pH 1.5. In stage 4, at 145°F., the viscosities were somewhat lower than for 110°F. at pH's above 6, but for pH's less than 6 viscosities were about the same at both 145 and 110°F.

The viscosities of the pulps entering stage 6 were 12.3 and 12.9 cp. (Tables III and IV), respectively, for the bleaches at 0.3% available chlorine and at 1.0% available chlorine. The effect of decreasing pH on stage 6 viscosities follows closely the pattern of the

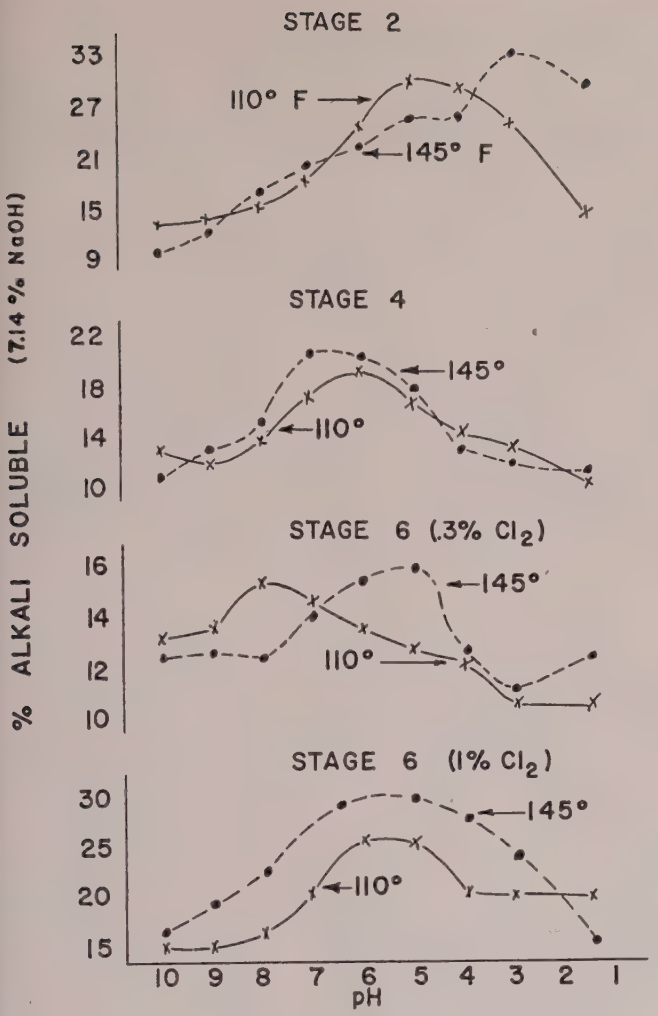

Fig. 4. Alkali solubility versus pH

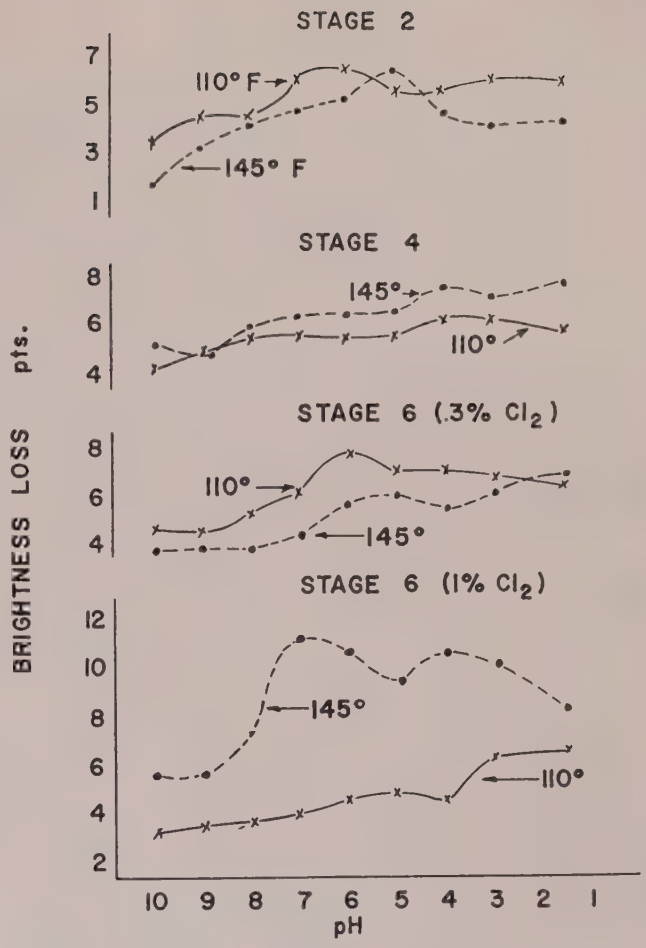

Fig. 5. Brightness loss versus pH

stage 4 viscosities. At 0.3% applied available chlorine the 145°F. viscosities were mostly higher than for 110°F.

Applying 1.0% available chlorine, a substantial excess, resulted in lower viscosities but did not change the pattern of response at different pH values.

It is interesting that the viscosities of the more purified pulps (stages 4 and 6) were lowest in the pH-6 range, whereas the lowest viscosities in stage 2 were at a pH of 3. Also, the rather drastic increase in temperature from 110°F. to 145°F. had relatively little effect on pulp viscosity.

Permanganate Number

Permanganate numbers were determined for the full pH range studied in stages 2 and 4 (Tables I and II), but only at pH 9 for the stage 6 bleaches (Tables III and IV). Figure 2 shows the effect of pH on permanganate number.

In the stage 2 bleaches, permanganate numbers at the end of the stage were at a minimum (around 1.5–1.4) in the 8 to 6 pH range, and highest at a pH of 3 and lower. In the stage 4 bleaches permanganate number decreased as the pH was lowered. Temperature had very little effect on permanganate number.

Brightness

The effect of pH on brightness is shown in Fig. 3. In stages 2 and 4 at 110°F. brightness was maximum in the 8 to 9 pH range, becoming progressively lower with decreasing pH. Increasing the temperature from 110 to 145°F. in stage 4 flattened the brightness curve somewhat with brightness least at pH 6, and increasing slightly at lower pH's.

In stage 6, with 0.3% applied available chlorine, brightness increased somewhat as the pH was lowered below 7. This effect was more pronounced at 145°F. than at 110°F. Applying 1.0% available chlorine in stage 6 produced an effect similar to stage 4 but at a higher brightness level.

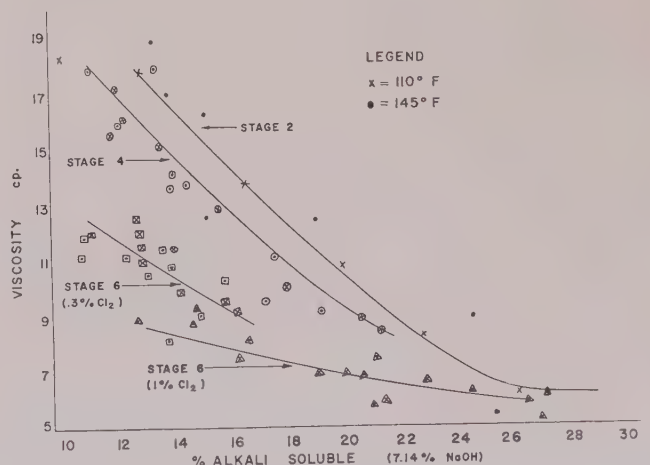

Fig. 6. Alkali solubility versus viscosity

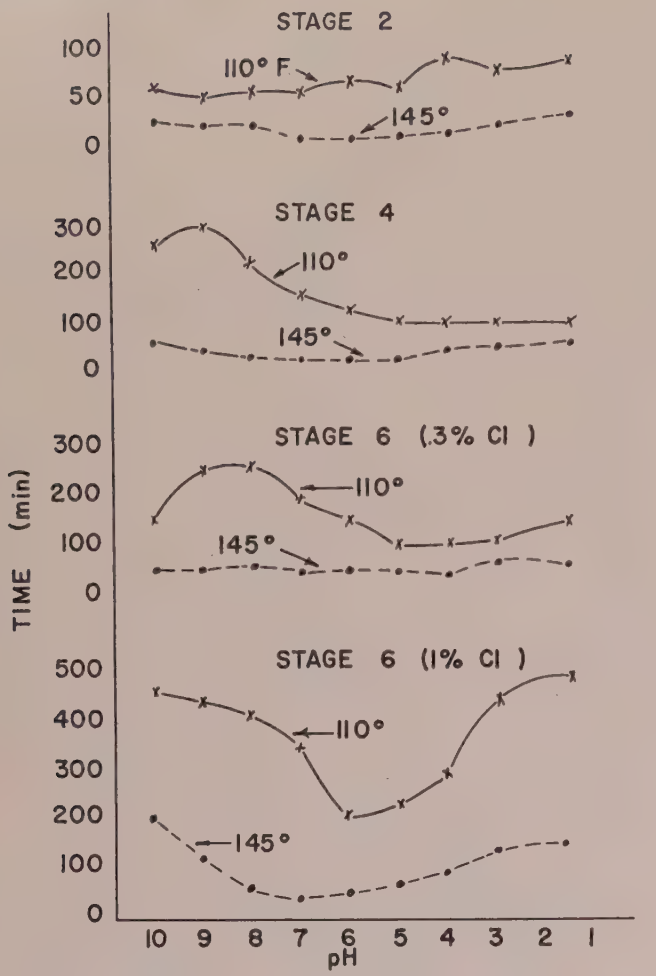

Fig. 7. Time for bleach consumption

Alkali Solubility

The percentage of a pulp that is soluble in hot 7.14% NaOH solution is a measure of the extent to which a pulp has been degraded by the chemicals, and conditions of treatment to which the pulp has been subjected. The effect of pH on alkali solubility in the hypochlorite bleaching stages studied is shown in Fig. 4.

The Figure shows that pulp degradation continues to increase in stage 2 at pH's well below 6.

In stage 4, maximum degradation occurs in the 6 to 7 pH range. Similarly, in stage 6 the greatest degradation occurs close to neutrality. The amount of applied available chlorine appears to have some influence on the pH level at which maximum degradation occurs, as well as on the relative amount of degradation.

Brightness Loss on Heat Fading

The effect on the amount of brightness lost on oven fading of the pulps is, in general, an increased loss as pH is lowered (Fig. 5). In stages 2 and 6 there is indicated a tendency for the loss to be maximum around pH 5 to 6. However, in all stages the tendency for increased loss with decreasing pH appears to dominate.

The Relationship of Viscosity to Alkali Solubility

From Fig. 1 and Fig. 4 a fairly close relationship between viscosity and hot alkali solubility should be expected. In Fig. 6 it is evident that it is possible to have a considerable range of viscosity at a given alkali solubility and vice versa. However, when considered by stages, there is a definite relationship.

Temperature, apparently, has little influence on this relationship. The amount of applied available chlorine, on the other hand, seems to have considerable bearing on the alkali solubility.

Time Required for Virtual Bleach Exhaustion

That pH has a decided effect on the rate of exhaustion of a given amount of applied available chlorine is well known. However, it was felt worth while to note the approximate elapsed times to virtual exhaustion of the applied bleach in the bleaches made in this study. Figure 7 shows the results of these observations.

In general, the time tends to be a minimum around pH 6 with both higher and lower pH's extending the length of time required. Higher temperature shortens the time drastically but does not change the general pattern.

SUMMARY

In the chlorine-hypochlorite-caustic extraction-hypochlorite-caustic extraction-hypochlorite bleaching sequence studied the effect of pH, while similar in the different hypochlorite stages was not identical.

Viscosities in stage 2 continued to decrease with lower pH's to the neighborhood of pH 3. Viscosities in stages 4 and 6 were lowest around pH 6. Temperature did not have much effect on the viscosity-pH relationship.

Permanganate number in stage 2 is lowest around pH 7, while in stage 4 it decreases with decreasing pH. Temperature has little effect.

Brightness appears to be affected more by the amount of available chlorine applied and temperature than by pH, although in stages 2 and 4 at 110°F., brightness drops as pH is lowered.

Increased solubility in hot alkali follows reduced viscosity fairly closely when compared in a given stage but does not necessarily correspond in the broader sense.

Brightness lost in oven fading increases with decreasing pH, in general, but the amount of applied chlorine and bleaching temperature have considerable effect.

The results of these studies indicate the necessity of careful control of pH in bleaching with hypochlorite, and that the effect of pH varies, depending on what bleaching stage of a multistage bleaching sequence is under consideration.

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Corrosion of Mild Steel in Alkaline Pulping Liquors

III. Special Effect of Sulfite Ion in Kraft White Liquor

RICHARD B. KESLER

In earlier work, it was observed that dual corrosion rates of mild steel in kraft white liquor were obtained at constant liquor corrosivities, when the corrosivity values were calculated according to Roald's corrosivity equation. At that time, the prediction was made that a family of curves would be obtained by plotting liquor corrosivity against corrosion rate, each curve being specific for a definite sulfite ion concentration. This paper presents the results of experiments that substantiate the prediction, and further define the role of sulfite ion in steel corrosion in white liquor. It was found that a six- or sevenfold increase in corrosion rate occurred upon a reduction in sodium sulfite, in the liquor, of only 0.3 g.p.l. The linear relationship between liquor corrosivity and steel corrosion rate begins to break down as the sodium sulfite content of the liquor is reduced to about 1.5 g.p.l.

A PREVIOUS study (*1*) of steel corrosion in white liquor brought to light the anomalous behavior of sulfite ion in the application of Roald's (*2*) corrosivity equation. Using the corrosivity equation (*1*) a dimensionless number is obtained for the corrosiveness of the liquor.

$$C = (k)\frac{(Na_2S_2O_3)\,(Na_2S)\,(NaOH + 0.4\ Na_2S)}{\sqrt{Na_2SO_3}} \qquad (1)$$

In experimental work, a plot of the corrosivity against corrosion rate should yield a straight line passing through the origin. A variation of the equation whereby the square root sign is omitted is called for under conditions of violent liquor agitation and low sulfite ion concentration. Liquor concentrations are expressed in grams per liter and k is a composite constant.

Roald (*2*) successfully applied his equation to the data of Haegland and Roald (*3*). In the application of the equation to corrosion data in which the liquors used contained relatively large amounts of sulfite (*4, 5*), Roald found an empirical relationship in which corrosion rates were directly proportional to the square root of the liquor corrosivity. The weight-loss tests of Haegland and Roald (*3*) were conducted in unstirred liquor at controlled temperature, while those experiments with liquor containing added amounts of sulfite were made in laboratory digesters in the presence of chips and under actual cooking conditions.

In the previous work cited (*1*), it was found that the corrosivity equation held very well until the sodium sulfite concentration fell to about 1 gram per liter. Then a linear relationship was obtained only by plotting corrosion rates against the square root of the corrosivity as was done by Roald (*2*). However, Roald found this relationship to exist only where the sulfite ion concentration was appreciable, while the opposite was found in this work. In addition, when the sulfite ion concentration dropped to the low values, a multifold increase in the corrosion rate took place. This is illustrated in Fig. 1, reproduced from the earlier work, where the upper curve was obtained from weight-loss tests in liquors containing 1 g.p.l. or less of sodium sulfite. The liquors used in the experiments represented by the lower curve contained more than 1 g.p.l. of sodium sulfite. As can be seen from Fig. 1, it is possible to observe two greatly differing corrosion rates at any given corrosivity. Whether the corrosion rate falls in the high or low range depends upon the sulfite ion concentration.

A prediction was made in the earlier work (*1*), in the absence of experimental data, that a family of curves, falling generally between the two curves in Fig. 1, should be obtained with the parameter for each curve being the sodium sulfite concentration in the liquor. This paper is a presentation of the results of experiments subsequently carried out in attempts to substantiate that prediction.

EXPERIMENTAL

A series of 28 weight-loss tests were made in kraft white liquor with the same steel used previously. Methods and procedures were identical to those of the earlier work, except that in these experiments, all of the white liquor was made by partial neutralization of an aqueous sodium hydroxide solution under oxygen-free conditions. A stock solution of liquor was stored under nitrogen and analyzed for sulfite, thiosulfate, sul-

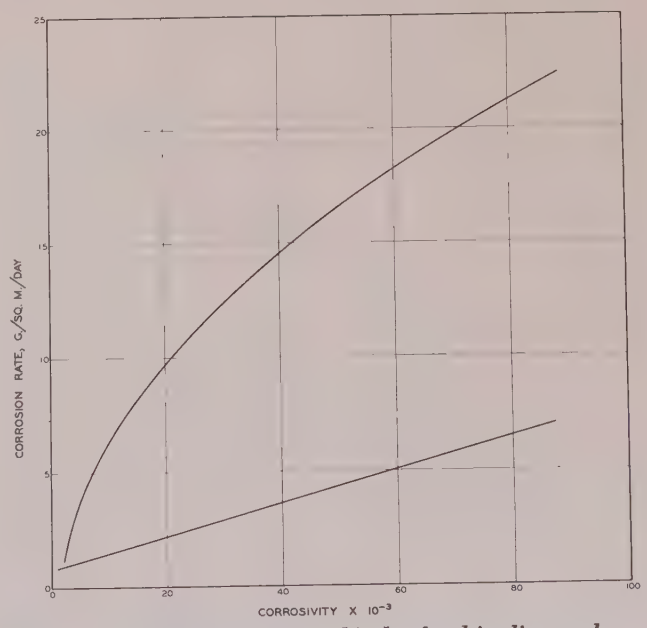

Fig. 1. Corrosion of mild steel in kraft white liquor showing dual corrosion rates at single corrosivity values

RICHARD B. KESLER, Research Aide, The Institute of Paper Chemistry, Appleton, Wis.

Table I. Effect of Sulfite Ion Concentration on Corrosion Rate of Mild Steel in Kraft White Liquor

Test no.	Liquor constituents, g.p.l. Na_2S	$NaOH$	$Na_2S_2O_3$	Na_2SO_3	Liquor corrosivity	Corr. rate, g./m.²/day[a]
1	39.7	102.3	3.79	0.99	17,900	8.80
	39.7	102.3	6.96	0.93	33,900	11.0
	39.7	102.3	10.3	0.90	50,800	13.6
	39.7	102.3	13.6	0.93	66,300	15.4
2	39.7	102.3	3.73	1.28	15,500	7.73
	39.7	102.3	6.98	1.21	29,700	9.87
	39.7	102.3	10.3	1.12	45,200	11.7
	39.7	102.3	13.4	1.20	57,400	13.2
3	39.7	102.3	3.66	1.42	14,500	7.36
	39.7	102.3	8.07	1.45	31,500	9.52
	39.7	102.3	11.3	1.39	44,800	11.1
	39.7	102.3	14.7	1.45	57,500	12.6
4	39.8	100.4	4.42	1.77	15,400	2.15
	39.8	100.4	9.00	1.80	31,100	3.50
	39.8	100.4	12.6	1.81	43,400	4.36
	39.8	100.4	17.3	1.77	59,000	5.58
5	39.8	100.4	5.38	2.75	15,000	2.02
	39.8	100.4	11.1	2.85	30,600	3.13
	39.8	100.4	15.2	2.79	42,200	3.87
	39.8	100.4	21.4	2.73	60,000	5.18
6	39.8	100.4	5.20	5.03	10,800	1.04
	39.8	100.4	10.3	5.10	21,100	1.84
	39.8	100.4	14.1	4.95	29,100	2.46
	39.8	100.4	19.1	5.00	39,800	3.50
7	39.8	100.4	12.7	14.46	15,300	1.44
	39.8	100.4	26.2	14.39	31,600	2.70
	39.8	100.4	35.2	14.15	43,200	3.74
	39.8	100.4	49.3	14.18	60,500	4.91

[a] Average of four steel samples.

fide, and hydroxide by the methods used previously. From these values, the corrosivity of the stock liquor was calculated, using equation (1). The corrosivity was altered to the desired values for the weight-loss tests by addition of sulfite and thiosulfate to smaller volumes drawn from the stock solution. The smaller volumes actually used for the tests were then re-analyzed for sulfite and thiosulfate to determine their exact concentrations.

The results of these experiments, together with the values for the liquor constituents, are presented in Table I. The corrosivity and corrosion rate values are shown in graphical form in Fig. 2.

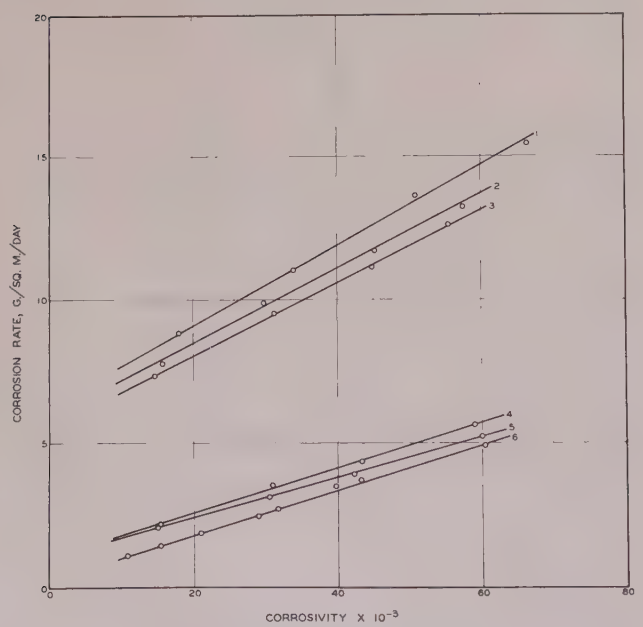

Fig. 2. Corrison of mild steel in kraft white liquor showing dependence of corrosion rate on sulfite ion concentration at a given liquor corrosivity

DISCUSSION

From the plotted results of the weight-loss tests shown in Fig. 2, it can be seen that the previous prediction of a family of curves has been substantiated. It can be seen from the table that the experiments were performed in groups of four, whereby the liquors in each group had a different corrosivity but contained essentially the same amount of sodium sulfite. This is reflected in Fig. 2 where each curve is drawn from four data points, with the exception of the lower curve. The data points from the last two groups of weight-loss tests, where the liquors contained about 5 and 14 g.p.l. of sodium sulfite, respectively, all fell on a single curve. Then, as the sodium sulfite content dropped below about 5 g.p.l., a new curve appeared for each concentration and corrosion rates slowly increased. When the sodium sulfite content dropped from 1.75 to 1.45, a difference of only 0.3 g.p.l., a six- or sevenfold increase in the corrosion rate occurred. As the sodium sulfite concentration decreased further, the corrosion rate continued to increase, but at about the same rate as initially observed. This behavior is illustrated by the grouping of the six curves in two regions in Fig. 2.

Evidently, a variance in the sodium sulfite content of the liquor at values above about 5 g.p.l. does not interfere with the application of the corrosivity equation, but as the sodium sulfite content falls much below 5 g.p.l., conditions are approached that result in a sudden change in the cathodically controlled corrosion mechanism. From Fig. 2 it appears that a decrease in the sodium sulfite content from 1.75 to 1.45 g.p.l. can under otherwise constant conditions, cause this shift in the reaction mechanism.

A more exact examination and definition of the critical sodium sulfite concentration presumed responsible for the sudden increase in corrosion rate is limited by present methods of liquor analysis. In a complex solution of salts such as white liquor, the best available method for determination of sulfite cannot be considered

as being more accurate than within about a tenth of a gram per liter of the true value in spite of reported values, in this paper, to the nearest hundredth of a gram per liter. It may be that a method for sulfite and thiosulfate developed recently by Bilberg (*6*) in Norway will yield more precise analytical results and thus allow more exact evaluation of the role of sulfite ion in steel corrosion.

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A Thermodynamic Study of the System Sodium Sulfite–Sodium Bisulfite–Water at 25°C.

ROBERT S. MORGAN

A thermodynamic study was made on the system sodium sulfite–sodium bisulfite–water at 25°C. The activity coefficients of sodium sulfite and sodium bisulfite in the various solutions of the system were calculated from isopiestic vapor-pressure measurements and dynamic gas saturation vapor-pressure measurements. The composition of the various solutions of the system were determined from the thermodynamic data. The significance of the results is discussed together with the applicability of the approach used in this study to future studies.

It is common knowledge that a sodium bisulfite solution exhibits a vapor pressure of sulfur dioxide. That is, when sodium bisulfite is dissolved in water, the odor of sulfur dioxide is very strong above the solution. It is evident from this observation that the sodium bisulfite must undergo a chemical reaction in the solution producing sulfur dioxide. It is also evident that a sodium bisulfite solution must contain more than two constituents. There is no known analytical method whereby the composition of a sodium bisulfite solution can be ascertained. However, it is possible to calculate the composition of such a solution at equilibrium from thermodynamic data.

The problem of the composition of a sodium bisulfite solution is a portion of the problem of the composition of the various solutions of the system sodium sulfite–sodium bisulfite–water. The object of this work was to make a thermodynamic study of this system; the final goal of the work was to determine the composition of the various solutions of the system. This system is only one example of the many solutions of mixed electrolytes involving chemical reaction that are found in the process liquors of the pulp and paper industry. No work has been found in the literature presenting a thermodynamic study of mixed electrolyte solutions involving chemical reaction.

NOMENCLATURE

a = activity
I = ionic strength
K = equilibrium constant defined by equation (3)
K' = equilibrium constant defined by equation (8)
ln = natural logarithm
m = molality of total sodium
p = vapor pressure, mm. of mercury
x = fraction of the total ionic strength contributed by a given constituent
z = valence
γ = mean molal activity coefficient

Subscripts

i = an ionic species
r = solution used as lower limit of integration in equation(7)
R = reference electrolyte
S = sulfur dioxide
w = water
1 = sodium sulfite
2 = sodium bisulfite

THERMODYNAMIC CONSIDERATIONS

The system sodium sulfite–sodium bisulfite–water is a part of the general system sulfur dioxide–sodium hydroxide–water. When sulfur dioxide is added to an aqueous solution of sodium hydroxide, the initial reaction is

$$2NaOH_{(aq)} + SO_{2(aq)} = Na_2SO_{3(aq)} + H_2O_{(l)} \qquad (1)$$

There is an equivalence point, called the first equivalence point, at a pH of about 10. At this equivalence point it is generaly assumed that equation (1) is displaced virtually completely to the right and that the solution is essentially a pure sodium sulfite solution.

If the addition of sulfur dioxide is continued past the first equivalence point, further reaction takes place as described by the following equation:

$$Na_2SO_{3(aq)} + SO_{2(aq)} + H_2O_{(l)} = 2NaHSO_{3(aq)} \qquad (2)$$

There is an equivalence point, called the second equivalence point, for this reaction at a pH of about 4. It is the general system described by equation (2) bounded by the two equivalence points that defines the specific system sodium sulfite–sodium bisulfite–water.

This equation elucidates the composition of a sodium bisulfite solution. The observation that there is a vapor pressure of sulfur dioxide above sodium bisulfite solutions indicates that equation (2) is not displaced completely to the right and that a sodium bisulfite solution contains sodium sulfite, sodium bisulfite, dissolved sulfur dioxide and water. It should be noted that in

Robert S. Morgan, Graduate Student, The Institute of Paper Chemistry, Appleton, Wis.; present address, Mohawk Paper Mills, Inc., Cohoes, N. Y. Work performed at The Institute of Paper Chemistry.

addition to the specific constituents indicated by the equation, there are small amounts of hydrogen, hydroxyl, and bisulfite ions present in the solution governed by the dissociation of the dissolved sulfur dioxide (sulfurous acid) and water. It is evident that the reaction expressed by equation (2) is important in determining the composition of the entire sodium sulfite–sodium bisulfite–water system.

The system sodium sulfite–sodium bisulfite–water can be defined in terms of the total sulfur dioxide and total sodium in the system. If sulfur dioxide, sodium hydroxide, and water are placed together in a closed vessel with an inert gas, nitrogen, at 25°C. and a total pressure of one atmosphere, there will be two phases present. Gibbs' phase rule states that such a system will have four independent variables. Two of these independent variables have already been specified—the temperature and the total pressure. Thus, the other two independent variables could be chosen as the total sulfur dioxide and the total sodium. However, it is more convenient to choose these other two independent variables as the total sodium and the ratio of total sulfur dioxide to total sodium. The four independent variables thus chosen for this study were the total sodium, the ratio of total sulfur dioxide to total sodium, a total pressure of one atmosphere, and a temperature of 25°C. In the case of sodium sulfite–bisulfite mixtures, the total sodium is expressed in terms of the total ionic strength.

The system sodium sulfite–sodium bisulfite–water has already been defined by means of the equivalence points of the reactions described by equations (1) and (2). It is evident from equation (1) that the first equivalence point occurs when the ratio of total sulfur dioxide to total sodium is 0.5; also, it is evident from equation (2) that the second equivalence point occurs when the ratio of total sulfur dioxide to total sodium is 1.0. Thus, the system sodium sulfite–sodium bisulfite–water is also defined as the system sulfur dioxide–sodium hydroxide–water when the ratio of total sulfur dioxide to total sodium has values from 0.5 to 1.0. There are three terms commonly used to define portions of these systems. When the ratio of total sulfur dioxide to total sodium is: (1) 0.5, the system is called a "sodium sulfite solution"; (2) 1.0, the system is called a "sodium bisulfite solution"; (3) between 0.5 and 1.0 the system is called "sodium sulfite-bisulfite mixtures" or "sodium sulfite-bisulfite solutions."

It is evident from the preceding discussion that the chemical reaction described by equation (2) is the main one to be considered in the system sodium sulfite–sodium bisulfite–water. The equilibrium equation for this reaction is

$$K = \frac{a_2^2}{a_1 a_S a_w} = \frac{\gamma_2^4 m_2^2}{\gamma_1^3 m_1 a_S a_w} \qquad (3)$$

where

K = the equilibrium constant
a_2 = the activity of sodium bisulfite
a_1 = the activity of sodium sulfite
a_S = the activity of dissolved sulfur dioxide
a_w = the activity of water
γ_2 = the mean ionic molal activity coefficient of sodium bisulfite
m_2 = the molality of sodium bisulfite
γ_1 = the mean ionic molal activity coefficient of sodium sulfite
m_1 = the molality of sodium sulfite

Mean ionic molal activity coefficients are used primarily in this study and are subsequently called simply "activity coefficients." The only exception to this is in the case of ions, where the symbol γ is used for the ionic activity coefficient. The usual conventions defining the standard states as given by Lewis and Randall (*1*) are used. The material balance equation for the total sodium in the system is

$$m_{Na} = 2m_1 + m_2 \qquad (4)$$

where m_{Na} = molality of total sodium in the system. [Equation (4) neglects the small number of sodium ions in the solution that are not accounted for by the concentrations of sodium sulfite and sodium bisulfite.] Equations (3) and (4) can be solved simultaneously for the molality of sodium sulfite, m_1, and the molality of sodium bisulfite, m_2, providing the other quantities in these two equations are known. The concentration of the other constituents in the system can be only estimated since activity coefficients for ions are not known. The methods of evaluation used for each of the other quantities in these equations are now discussed.

THERMODYNAMIC DATA

Activity Coefficients of Sodium Bisulfite

The activity coefficients of sodium bisulfite in aqueous solution were calculated from water vapor-pressure measurements on sodium bisulfite solutions. It was possible to measure the vapor pressure of sulfur dioxide above the sodium bisulfite solutions simultaneously with the water vapor-pressure measurements by using an apparatus similar to that used by Johnstone (*2*). Johnstone's apparatus was modified slightly by placing a presaturating flask similar to those described by Taylor (*3*) in the system before the first equilibrium tube. The procedure that was used was essentially the same as Johnstone's procedure except that the method of using the Vanier bulb was modified by using sodium hydroxide as the absorbent for sulfur dioxide and by using a weighing procedure that permitted weighing the bulb to the nearest 0.1 mg. The amount of sulfur dioxide absorbed was determined by oxidizing the absorbed sulfur dioxide with peroxide and titrating the excess sodium hydroxide with standard acid. The constant temperature bath was maintained at 25.00 ± 0.05°C.

The sodium bisulfite solutions were prepared from a stock sodium bisulfite solution by dilution with deaerated water. The stock solution was prepared by adding the stoichiometric amount of sulfur dioxide to a concentrated sodium hydroxide solution so that the ratio of total sulfur dioxide to total sodium was 1.0. Oxidation of the solutions was minimized by keeping the solutions under nitrogen and by adding 0.1% of hydroquinone to the stock bisulfite solution.

The results of the vapor-pressure measurements are given in Table I. With the exception of the data for the 7-molal solution, the values given in the table are the mean of five determinations; the values for the 7-molal solution are the mean of four determinations. The standard error of each value in the table is less than 0.5% except for the sulfur dioxide vapor-pressure values for the 0.57- and the 1.0- molal solutions; in these two cases, the absolute values of the standard error are about the same as they are for the other concentrations.

Table I. Vapor Pressures of H_2O and SO_2 Above $NaHSO_3$ Solutions at 25°C.

Total sodium molality, m_{Na}	*H_2O vapor press., mm. Hg*	*SO_2 vapor press., mm. Hg*
0	23.76 ...	... ...
0.5723	23.38 (0.4%)[a]	1.01 (2%)
1.048	23.08 (0.3%)	1.80 (1%)
1.943	22.57 (0.2%)	3.64 (0.2%)
4.745	20.65 (0.3%)	9.59 (0.2%)
7.015	19.57 (0.4%)	13.98 (0.1%)

[a] The number in parenthesis after each value is the standard error of the value expressed as a percentage of the value.

These data have been plotted in Fig. 1. The equations for the regression lines calculated from the data are given on the figure. It is believed that the water vapor-pressure data as represented by the regression line equation have a standard error of about 0.8%. The standard error of the sulfur dioxide vapor-pressure data as represented by the regression line equation is believed to be 0.2 to 0.3 mm. of mercury or about 0.5% over most of the range of the data.

The activity coefficients of sodium bisulfite in aqueous solution were calculated from equation (5):

$$\ln (I\gamma_2) = \ln (I_R\gamma_R) - \frac{55.51}{2} \int_{a_w=1}^{a_w} \left\{ -x_1 \left(\frac{\partial(1/I)}{\partial x_2} \right)_{a_w} + 1/I - 1/I_R \right\} d \ln a_w \quad (5)$$

where

I = total ionic strength
$x_1 = I_1/I$
$x_2 = I_2/I$

The total ionic strength is defined by

$$I = \sum_i m_i z_i^2 \quad (6)$$

where z_i = valence of the ion i. The subscript R in equation (5) designates a reference solution. Equation (5) is a form of the McKay-Perring equation (*4*) suggested by Bonner and Holland (*5*). It is designed to be used with isopiestic vapor-pressure measurements. In the isopiestic method, two solutions are equilibrated in a closed vessel at constant temperature until the vapor pressures (or more strictly, the activities) of the water in both solutions are the same. Thus, in equation (5), the quantities designated with the subscript R are the values of the quantities for the reference solution that is isopiestic with the sodium bisulfite solution for which the calculation is being made. In this case, a given sodium bisulfite solution would be equilibrated isopiestically with a reference solution; sodium chloride is the most common reference solution because its activity-coefficient data are well established (*6*). Since the water vapor-pressure data for sodium bisulfite were measured directly, the vapor-pressure data were converted to isopiestic data by determining the concentration of the sodium chloride solution that was isopiestic with each sodium bisulfite solution of interest.

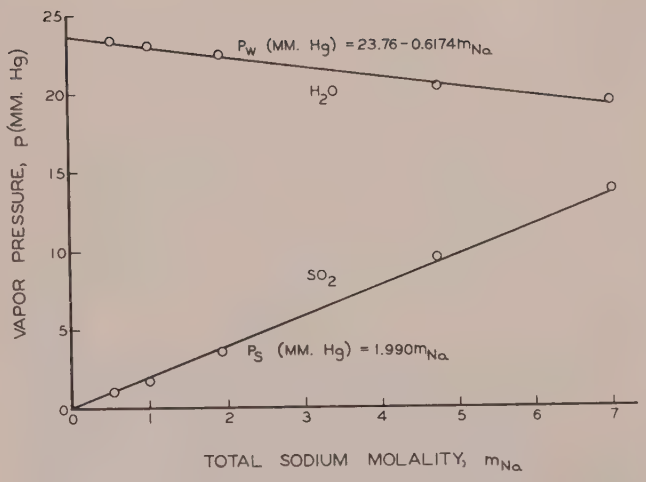

Fig. 1. Vapor pressures of H_2O and SO_2 above $NaHSO_3$ solutions at 25°C.

The activity-coefficient data from 0.4 to 7 molal were calculated directly from the equation. The activity-coefficient data below 0.4 molal were obtained by extrapolation. The values for the activity coefficients of sodium bisulfite calculated in this manner are given in Table II and Fig. 2 in the column and curve, respectively, designated 1.0. It is estimated that the standard error of the activity-coefficient data for sodium bisulfite in sodium bisulfite solutions is about 8%.

The activity coefficients of sodium bisulfite in the various sodium sulfite-bisulfite mixtures were also calculated from equation (5). The data used for this calculation were isopiestic data for the sodium sulfite solutions, isopiestic data determined for sodium-bisulfite solutions when the molal ratio of sulfite to bisulfite was 1:1, and the converted vapor-pressure data for sodium bisulfite solutions. The isopiestic data for sodium sulfite solutions were determined as a part of the study of this system in order to calculate the activity coefficients of sodium sulfite in sodium sulfite solutions; this work has been submitted for publication elsewhere (*7*). The isopiestic data for the sulfite-bisulfite solutions were obtained using the same apparatus and procedure that were used in the case of sodium sulfite. It is believed that the isopiestic data in both cases have a standard

Table II. Activity Coefficients of Sodium Bisulfite in Sodium Sulfite-Bisulfite Solutions at 25°C.

Total ionic strength, I	*Total moles sulfur dioxide/total moles sodium* 0.5	0.6	0.7	0.8	0.9	1.0
0.1	0.705	0.705	0.705	0.705	0.705	0.705
0.2	0.613	0.613	0.613	0.613	0.613	0.607
0.3	0.550	0.550	0.550	0.550	0.550	0.542
0.4	0.505	0.505	0.505	0.505	0.505	0.492
0.5	0.475	0.475	0.475	0.475	0.474	0.464
0.65	0.476	0.464	0.451	0.446	0.440	0.434
0.8	0.497	0.469	0.441	0.427	0.416	0.410
1.0	0.517	0.473	0.429	0.406	0.394	0.386
2.0	0.606	0.500	0.393	0.343	0.330	0.321
3.0	0.657	0.516	0.374	0.311	0.301	0.292
4.0	0.694	0.529	0.367	0.294	0.285	0.275
5.0	0.727	0.547	0.367	0.286	0.277	0.264
6.0	0.773	0.574	0.373	0.283	0.271	0.257

Table III. Molalities of Isopiestic Na_2SO_3-$NaHSO_3$ and NaCl Solutions at 25°C.

Molality of NaCl, m_R	*Total ionic strength of Na_2SO_3–$NaHSO_3$ solution, I*
0.2962 (0.14%)[a]	0.4764 (0.09%)
1.150 (0.03%)	2.001 (0.01%)
2.384 (0.03%)	4.364 (0.02%)
2.993 (0.06%)	5.490 (0.08%)
3.462 (0.03%)	6.327 (0.08%)
3.679 (0.01%)	6.709 (0.03%)

[a] The number in parenthesis after each value is the standard error of the value expressed as a percentage of the value.

error of about 0.1%. The isopiestic data for the sulfite-bisulfite solutions are given in Table III; the values in the table are the means of three replicates.

These three sets of isopiestic data were plotted together and smooth curves were drawn through the data to permit interpolation of the data for the values of x_1 used in the equation. Activity-coefficient data for mixtures with a total ionic strength of 0.65 and higher were calculated directly from the equation. The activity-coefficient data for values of the total ionic strength below 0.65 were determined by extrapolating the mixture data to infinite dilution. These data are given in Table II and Fig. 2. The values of the activity coefficients of sodium bisulfite when the ratio of total sulfur dioxide to total sodium is 0.5 were obtained from the other activity-coefficient data by extrapolation.

Activity Coefficients of Sodium Sulfite

An equation analogous to equation (5) can be written to calculate the activity coefficients of sodium sulfite in the various sulfite-bisulfite mixtures. The equation is

$$3 \ln (I\gamma_1/I_{(r)}\gamma_{1(r)}) = 2 \ln (I_R\gamma_R/I_{R(r)}\gamma_{R(r)}) - 55.51\int_{a_{w(r)}}^{a_w} \left\{3x_2\left(\frac{\partial(1/I)}{\partial x_1}\right)_{a_w} + 3/I - 1/I_R\right\} d \ln a_w \quad (7)$$

This equation was obtained by integrating an equation analogous to the differential form of equation (5) using a solution of finite, dilute concentration designated by the subscript r for the lower limit of integration. It was necessary to use this form of the equation rather than the form used for equation (5) because the extrapolation required to evaluate the integral could not be performed with sufficient accuracy. The data used for these calculations were the same as those used for the calculation of the sodium bisulfite activity-coefficient data for the sulfite-bisulfite mixtures. The activity-coefficient ratios were calculated from the equation for total ionic strengths of 0.5 and above. The activity coefficients were calculated from these ratios by assuming that the

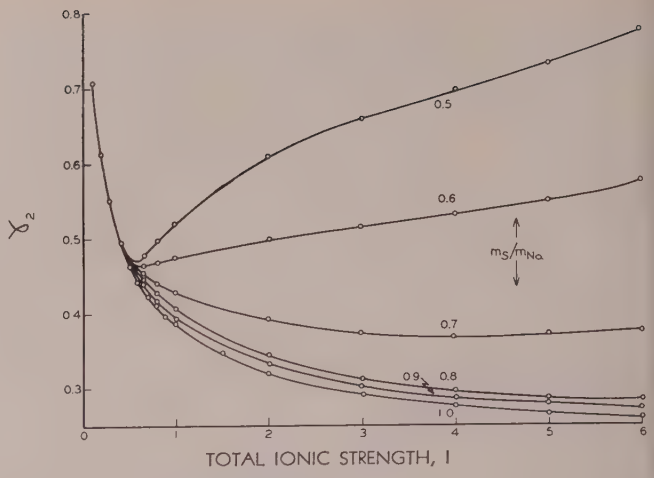

Fig. 2. Activity coefficients of $NaHSO_3$ in Na_2SO_3-$NaHSO_3$ solutions at 25°C.

activity coefficients of sodium sulfite in all of the mixture solutions at a total ionic strength of 0.5 were equal to the activity coefficient of sodium sulfite in pure solution at the same total ionic strength. The activity-coefficient data determined in this manner are given in Table IV and Fig. 3. The activity coefficients of sodium sulfite in sodium sulfite solutions (7) are given in Table IV and Fig. 3 in the column and by the curve, respectively, designated 0.5. The values of the activity coefficients of sodium sulfite when the ratio of total sulfur dioxide to total sodium is 1.0 were obtained from the other activity-coefficient data by extrapolation.

It is estimated that the standard error of the activity-coefficient data for sodium sulfite and sodium bisulfite in the sulfite-bisulfite mixtures is the same as that for sodium bisulfite in sodium bisulfite solutions, or about 8%. Any error introduced by making the assumption that the sodium sulfite activity-coefficient data for the sulfite-bisulfite mixtures converge at total ionic strength of 0.5 is well within this value of the standard error. The activity-coefficient data for sodium sulfite in sodium sulfite solutions were estimated to have a standard error of about 0.5%.

Significance of the Activity-Coefficient Data

It is believed that the activity-coefficient data for sodium sulfite and sodium bisulfite in sodium sulfite-bisulfite solutions are the first of their kind to be calculated from experimental data. Han and Bernardin (*8*) calculated the activity coefficients of sodium bi-

Table IV. Activity Coefficients of Sodium Sulfite in Sodium Sulfite-Bisulfite Solutions at 25°C.

Total ionic strength, I	*Total moles sulfur dioxide/total moles sodium*					
	0.5	*0.6*	*0.7*	*0.8*	*0.9*	*1.0*
0.1	0.571	0.571	0.571	0.571	0.571	0.571
0.2	0.486	0.486	0.486	0.486	0.486	0.486
0.3	0.438	0.438	0.438	0.438	0.438	0.438
0.4	0.404	0.404	0.404	0.404	0.404	0.404
0.5	0.379	0.379	0.379	0.379	0.379	0.379
0.65	0.352	0.358	0.372	0.376	0.391	0.402
0.8	0.331	0.345	0.364	0.374	0.395	0.409
1.0	0.308	0.324	0.353	0.372	0.400	0.419
2.0	0.248	0.267	0.314	0.364	0.399	0.420
3.0	0.218	0.238	0.295	0.366	0.401	0.420
4.0	0.199	0.223	0.287	0.379	0.414	0.432
5.0	0.188	0.217	0.288	0.400	0.438	0.460
6.0	0.181	0.216	0.294	0.423	0.473	0.490

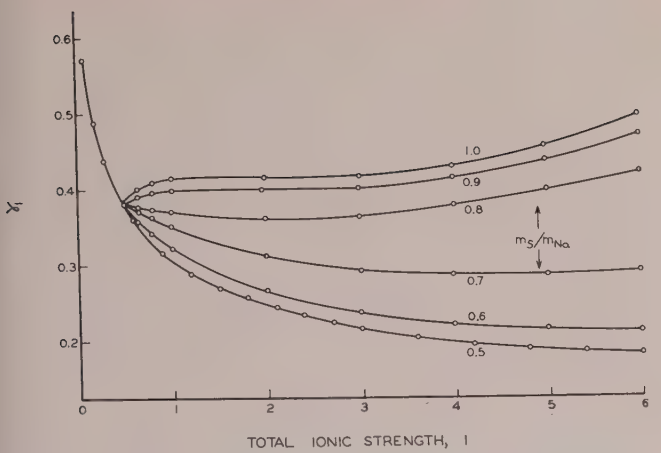

Fig. 3. Activity coefficients of Na_2SO_3 in Na_2SO_3-$NaHSO_3$ solutions at 25°C.

carbonate in sodium carbonate-bicarbonate solutions from an equation analogous to equation (3):

$$\gamma_{HCO_3^-} = \left(\frac{K' a_{H_2O} a_{CO_2} m_{CO_3^-} \gamma_{CO_3^-}}{m^2_{HCO_3^-}}\right)^{1/2} \qquad (8)$$

These authors showed from considerations of the Debye-Hückel interionic theory and the definition of mean ionic activity coefficients that at infinite dilution the activity coefficient of sodium bicarbonate equals the activity coefficient of bicarbonate ions and the activity coefficient of sodium carbonate equals the square root of the activity coefficient of carbonate ions. It is not known how well these relationships hold as the concentration is increased. Nevertheless, Han and Bernardin assumed that these relationships are reasonably valid at finite concentrations and calculated the activity coefficients of sodium bicarbonate from equation (8).

These workers evaluated each of the quantities in equation (8) as follows: (1) The equilibrium constant K' from data in the literature; (2) the activity of water a_{H_2O} by assuming that it is equal to its mole fraction in accordance with Raoult's law; (3) the activity of carbon dioxide a_{CO_2} from carbon dioxide vapor-pressure data for the sodium carbonate-bicarbonate system; (4) the molalities of carbonate and bicarbonate ions by stoichiometric calculations from assumed values of the fraction of sodium as bicarbonate and the total ionic strength, the calculation parameters; (5) the activity coefficients of carbonate ions from the activity-coefficient data for sodium carbonate. It is evident that there are several questionable assumptions in this calculation procedure. The most serious of these are the assumptions of the relationships between the ionic and molal activity coefficients, and the assumption that the activity coefficients of the carbonate ions are not a function of the fraction of sodium as bicarbonate. It is not possible to assess the magnitude of the errors introduced into the calculations by these assumptions without additional experimental data. It should also be noted that it is possible that all of the assumptions are valid for the sodium carbonate-bicarbonate system.

The activity-coefficient data calculated by Han and Bernardin were obtained as a function of the fraction of sodium as bicarbonate and the total ionic strength. However, they reported the activity-coefficient data as a function of the total ionic strength only. The variation of the data with the fraction of sodium as bicarbonate was less than 5%; thus, these authors did not feel justified in reporting the data as a family of curves similar to the data for sodium bisulfite in Fig. 2 on the basis of their data alone because of the assumptions involved in their calculation procedure.

It is now possible to examine the activity-coefficient data for sodium bicarbonate in the light of the activity-coefficient data obtained in this study for sodium bisulfite and sodium sulfite. The activity-coefficient data for sodium bisulfite indicate that the variation of the activity-coefficient data of sodium bicarbonate with the fraction of sodium as bicarbonate is significant. Indeed, examination of the original plot of the bicarbonate data showed that a definite and consistent variation in the individual data points with the fraction of sodium as bicarbonate comparable to that for sodium bisulfite exists. Furthermore, this plot also shows evidences of convergence of the family of curves at low concentrations and divergence at high concentrations similar to the data for sodium bisulfite. This convergence and divergence is more pronounced in the data for the activity coefficients at 50 and 65°C.

The variation of 5% in the activity-coefficient data of sodium bicarbonate with the fraction of sodium as bicarbonate is considerably smaller than the similar variation of 80% found for the sodium bisulfite data. If activity-coefficient data for carbonate ions having a variation with the fraction of sodium as bicarbonate comparable to that for sodium sulfite were used for the calculations, then the resulting activity-coefficient data for sodium bicarbonate would show a variation with the fraction of sodium as bicarbonate of up to 50%. It should be noted, however, that the amount of this variation cannot be inferred from the data on the sulfite-bisulfite system; it can only be said that a certain amount of variation is expected and that the amount of variation obtained for the activity coefficients of sodium bicarbonate is significant. The activity-coefficient data for sodium bicarbonate calculated from experimental measurements by Busche (*9*) indicate that the variation of the activity coefficients with the fraction of sodium as bicarbonate may be considerably smaller than the comparable variation obtained for sodium bisulfite. Busche has shown that these calculated activity-coefficient data for sodium bicarbonate are consistent with those derived from measurements of the pH of sodium carbonate-bicarbonate solutions and the solubility of sodium bicarbonate in sodium carbonate-bicarbonate solutions.

Figures 2 and 3 show that the activity-coefficient data for both sodium sulfite and sodium bisulfite converge as the ionic strength decreases. The data for sodium bisulfite show that the well-known Lewis and Randall assumption, that the activity coefficients of an electrolyte in a mixed electrolyte solution are a function of the total ionic strength of the solution and not the kinds of ions present, holds for the sodium-bisulfite data up to an ionic strength of about 0.5. However, above an ionic strength of 0.5, the use of this assumption could lead to an error of up to 70% in the activity coefficient.

The pH data for sodium bisulfite solutions reported in the literature (*10*, *11*) show that a plot of the pH versus molality goes through a sharp minimum at about 0.05 molal and a maximum at about 0.35 molal. The difference between the value of the pH at the minimum and the maximum is about one pH unit—meaning, of course,

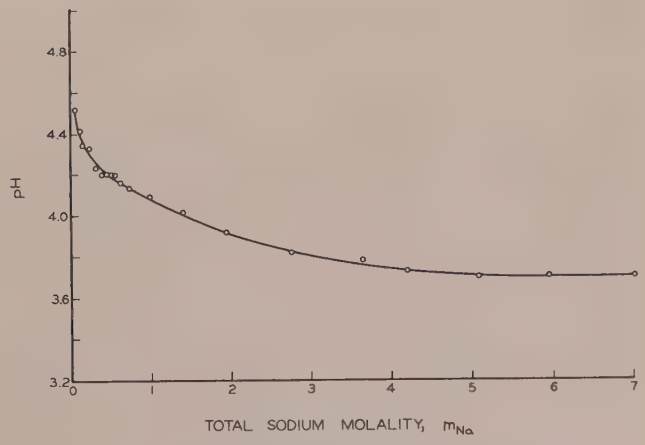

Fig. 4. pH of $NaHSO_3$ solutions at 25°C.

a tenfold change in the hydrogen ion activity. Figure 4 shows the pH data obtained in this study; they do not show any evidence of such a phenomenon.

The pH of a sodium bisulfite solution can be calculated from the equations for the ionization constants of sulfurous acid. Even though the values of pH calculated from these equations are only approximate when the concentration is increased from infinite dilution, the functional relationship should still be generally the same. The values of the pH calculated from these equations for molalities from 0.1 to 0.65 all lie on a smooth curve without maxima or minima; this curve does not differ significantly from the curve of the measured pH values over the range of molality from 0.1 to 0.3. It was estimated from these equations that abrupt changes in the activity-coefficient data of the order of 50% would be necessary in order to produce the variation in the pH data observed by the other workers. This amount of variation is extremely unlikely, especially in these dilute solutions. Hence, it is concluded that the pH data reported by these other workers are thermodynamically inconsistent.

Calculation of Water Activity

The activity of water, a_w, for any given aqueous solution is equal to the ratio of the fugacity of the water vapor above a given solution to the fugacity of pure water at the same temperature. In this case, vapor pressure can be substituted for fugacity within the accuracy of the experimental data.

Calculation of the Equilibrium Constant

The equilibrium constant, K, can be shown to be equal to the ratio of the first and second ionization constants of sulfurous acid. The value of the first ionization constant was determined from the values reported in the recent literature (*12–15*). One value (*12*) was discarded because of the lower order of accuracy of the work; another value (*13*) was discarded because it was over 14 standard errors away from the mean of the four remaining values, 0.0128. It is estimated that this value has a standard error of about 5%. There are only two values of the second ionization constant reported in the literature that were obtained using methods of high accuracy. Both sources (*13, 14*) give 6.24×10^{-8}; it is estimated that the standard error of this value is about 5%.

Calculation of the Sulfur Dioxide Activity

It can be shown that the activity of sulfur dioxide, a_S, can be evaluated from the Henry's law constant for the sulfur dioxide-water system and the vapor pressure of sulfur dioxide above the particular solution of the sulfite-bisulfite system of interest. The Henry's law constant was evaluated using the method of Johnstone and Leppla (*15*) by combining the solubility of sulfur dioxide in water data of Parkinson (*16*) with that of Johnstone and Leppla. This calculation yielded a value of 1.28 moles per 1000 g.-atm.; the previous value obtained by Johnstone and Leppla was 1.26 moles per 1000 g.-atm. based on their vapor-pressure data alone. It is estimated that the standard error of the value of 1.28 moles per 1000 g.-atm. is about 5%.

No data are available on the vapor pressure of sulfur dioxide above sodium sulfite-bisulfite solutions at 25°C. Johnstone, Read, and Blankmeyer (*17*) have measured the vapor pressure of sulfur dioxide above some sodium sulfite-bisulfite solutions at 35°C. and higher temperatures. These data were extrapolated to 25°C. and plotted together with the sulfur dioxide vapor pressure data above sodium bisulfite solutions obtained in this study. The accuracy of the extrapolated data and the amount of data are insufficient to make more than the following qualitative statements about the solutions at 25°C. The vapor pressure of sulfur dioxide:

(1) increases with increasing total sodium;

(2) increases with increasing ratio of total sulfur dioxide to total sodium;

(3) is less than 1 mm. of mercury at values of the ratio of total sulfur dioxide to total sodium below 0.95;

(4) is less than 0.5 mm. of mercury at values of the ratio of total sulfur dioxide to total sodium less than 0.9;

(5) is less than 0.1 mm. of mercury at values of the ratio of total sulfur dioxide to total sodium less than 0.8.

DETERMINATION OF THE EQUILIBRIUM COMPOSITION

Composition of Sodium Bisulfite Solutions

The equilibrium equation, equation (3), was solved simultaneously with equation (4) to obtain the concentration of sodium sulfite and sodium bisulfite in sodium bisulfite solutions. The results are given in Table V.

Estimations of the standard errors of the molalities of sodium sulfite and sodium bisulfite were made by calculating the propagation of the errors of the individual quantities in the equilibrium equation. Thus, the standard error of the molality of sodium sulfite was estimated to be about 17% at all concentrations; the standard error of the molality of sodium bisulfite was estimated to be 0.2% for a 0.1-molal solution diminishing to about 0.003% for a 6-molal solution. This somewhat unusual result stems partly from the nature of the equilibrium equation and partly from the fact that the molality of sodium bisulfite is much larger than the molality of sodium sulfite.

It can be shown from the data in Figs. 2 and 3 and in Table V that the effect of the presence of constituents other than sodium bisulfite on the sodium-bisulfite activity-coefficient data is well within the standard deviations of the activity-coefficient data.

The various chemical equilibria involved and the data of Table V can be used to show that at a molality of

total sodium of 0.1 (about 0.1 molal) about 0.8% of the sodium bisulfite in a sodium bisulfite solution is dissociated, producing about 0.8 mole per cent of constituents other than sodium bisulfite in the solution; these values decrease with increasing concentration so that when the molality of total sodium is 6.0, about 0.03% of the sodium bisulfite is dissociated, producing about 0.03 mole per cent of constituents other than sodium bisulfite.

Composition of Sodium Sulfite Solutions

The degree of hydrolysis of sodium sulfite in a 0.1-molal sodium sulfite solution was estimated to be about 0.1%; it decreases with increasing concentration until at two molal it is estimated to be about 0.007% (*7*). These data can be used together with a consideration of the chemical equilibria involved to show that the products of hydrolysis in a 0.1-molal sodium sulfite solution comprise less than 0.2 mole per cent of the total moles of constituents in the solution and that this quantity decreases with increasing concentration until at two molal, it is about 0.015%.

Table V. Composition of Sodium Bisulfite Solutions at 25°C.

Molality total sodium	*Molality Na_2SO_3*	*Molality $NaHSO_3$*
0.1	0.000376	0.09924
0.2	0.000687	0.19863
0.3	0.000906	0.29819
0.4	0.001010	0.39798
0.5	0.001040	0.49792
0.7	0.001020	0.69796
1.0	0.000911	0.99818
1.5	0.000887	1.49823
2.0	0.000895	1.99821
3.0	0.000936	2.99813
4.0	0.000918	3.99816
5.0	0.000841	4.99832
6.0	0.000731	5.99854

Composition of Sodium Sulfite-Bisulfite Solutions

The composition of the various sodium sulfite-bisulfite solutions cannot be calculated because only qualitative sulfur-dioxide vapor-pressure data are available. However, it can be shown by qualitative reasoning that: (1) When the total sulfur dioxide to total sodium ratio is less than 0.9, the dissociation of sodium bisulfite is less than 0.1%, and that the relative amounts of sodium sulfite and sodium bisulfite present are essentially the same as the amounts calculated stoichiometrically. (2) When the ratio of total sulfur dioxide to total sodium is between 0.9 and 0.95, the dissociation of sodium bisulfite is estimated to be less than 0.2%. (3) When the ratio of total sulfur dioxide to total sodium is between 0.95 and 1.0, the per cent of dissociation of sodium bisulfite has values between the per cents dissociated at ratios of total sulfur dioxide to total sodium of 0.95 and 1.0. The concentrations of the minor constituents can be shown to be quite negligible for most of the sulfite-bisulfite solutions; where the concentrations are not negligible, they can be inferred from the previous discussions of the compositions of sodium sulfite and sodium bisulfite solutions.

SIGNIFICANCE OF THE COMPOSITION DATA AND SUGGESTIONS FOR FUTURE STUDY

It is believed that this study on the system sodium sulfite–sodium bisulfite–water represents the first attempt to make a thermodynamic study of mixed electrolyte solutions involving chemical reactions. The thermodynamic data obtained in this study have been used either to calculate or estimate the equilibrium composition of the various solutions of the system. This is particularly significant when it is realized that there is no known analytical method whereby the composition of a mixed electrolyte solution involving chemical reaction can be ascertained.

It might be concluded that the small difference between the composition of the solutions of the system arrived at in this study and the composition calculated from purely stoichiometric considerations is of little consequence. This conclusion may well be valid for some applications of the data; however, for equilibrium applications, no quantity that is present in the equilibrium relationships can be neglected. For example, it was estimated that the activity of sulfur dioxide in a 0.0333-molal sodium sulfite solution was 3×10^{-14}. The magnitude of this quantity is negligibly small; however, because of the mathematical nature of the equilibrium equation, equation (3), it cannot be neglected in consideration of the equilibria in sodium sulfite solutions.

The importance of the minor constituents in a sodium sulfite solution can be illustrated further by considering the Arbiso pulping process (*11*). It is claimed that the Arbiso process, a process for pulping using sodium sulfite solutions as the pulping liquor, is distinguished from the normal acid sulfite pulping process by the absence of sulfur dioxide in the cooking liquor. That this claim is fallacious is evident from previous discussion of the composition of sodium bisulfite solutions. It has been suggested that the active agent in acid sulfite pulping is sulfurous acid. If this is also true for the Arbiso process, then it follows that the presence of small amounts of dissolved sulfur dioxide may be the most important part of the system from a pulping viewpoint.

The methods of calculation used in this study have indicated the general usefulness of the McKay-Perring equation for the calculation of activity coefficients of the constituents of mixed electrolyte solutions. Indeed, the most promising approach to further study of complex electrolyte solutions appears to be the application of the McKay-Perring equation to isopiestic vapor-pressure data. The outstanding advantages of this approach are: (1) the ease with which isopiestic data of high accuracy can be obtained; (2) the applicability of the McKay-Perring equation to systems containing any number of constituents; (3) the possibility of obtaining activity-coefficient data for an electrolyte which cannot be prepared in pure solution. There are two disadvantages to the approach: (1) tedious, iterative calculation procedures are required; (2) evaluation of the integrals when the lower limit of integration is infinite dilution may be uncertain. The first disadvantage can be offset somewhat by the use of electronic computing devices. Obtaining careful isopiestic measurements on very dilute solutions may completely eliminate the second disadvantage for many systems.

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The Use of Surfactant in the Cold Caustic Pulping of Aspenwood

ROBERT A. DIEHM, HARRY L. LARSON, and SIEGFRIED MEINSTEIN

In an attempt to enhance penetration of cold soda liquor into hardwood, the effect of the addition of wetting agents to the pulpwood, and to the pulping liquor was studied. Of numerous surfactants examined, sodium xylene sulfonate (SXS) appeared to be most suitable. Pulping experiments using aspenwood chips, indicate that a number of other benefits may be derived from the use of SXS as a cold soda pulping adjunct. Thus, improvement in pulp quality was reflected in somewhat better strength properties, as evidenced by bursting and tear tests, as well as folding endurance. Also, the SXS-treated fibers are softer, defiber faster and more readily, requiring less power in refining and expelling processes. The most pronounced advantage in using SXS would appear to be in the increased pulp yield obtained. Precise cost analysis for use of SXS on a plant-scale production cannot be made from limited volume runs. However, SXS is not at all consumed or altered during digestion; it retains its original activity when recycled with the recovered caustic liquor. Efficient liquor recovery would thus minimize cost, and power savings could completely offset any expenditures on SXS, leaving quality improvement and pulp yield increase as a bonus. In comparing pulps made with SXS and cold caustic with those from other pulping processes, it was found that the former very definitely are competitive with neutral sulfite pulps.

In any pulping process, there is a constant challenge to (a) improve the pulp quality, (b) increase the yield, and (c) reduce operating costs. Very often, one of these objectives can be reached at the expense of another, and usually it is most difficult to alter pulping conditions in such a way as to master all three challenges at the same time.

It was felt by us, that use of a suitable surfactant in the pulping of wood could possibly achieve advances in the three enumerated categories simultaneously (or at least in two, without affecting the third). This, we thought, could be accomplished by making more efficient use of chemicals in the pulping liquor through a surfactant. For example, by enhancing the dispersion and uniform penetration of the effective liquor to all fibers in a wood chip, actual digesting time as well as liquor concentration might be decreased for an equally efficient job, without unnecessarily fracturing fibers in some portions of the chip where a great differential in rate of liquor penetration might exist.

An alkaline process was chosen in our work, since, contrary to the usual conception, it has been found that basic solutions penetrate into wood more slowly than do acid ones. The alkaline solution swells the cell walls of the wood, producing wider and more numerous diffusion paths across the fibers, and permits the diffusion of solute at rather equal rates in various directions throughout the wood. By reducing the surface tension of the digesting liquor, faster and more even penetration of the latter into the wood should be effected. Thus, a less concentrated pulping liquor might do an equally effective and even more uniform job, in less time.

On the other hand, a surfactant may increase the pulping cost to some extent, particularly if a major portion of it is lost in the process. Therefore, the cold caustic pulping process was chosen for our investigation. This process is one of the few in which a major portion of the spent pulping liquors may be re-used directly. Thus, most of the the surfactant (unless actually con-

Robert A. Diehm, Professor, Department of Paper Technology, Western Michigan University, Kalamazoo, Mich., Harry L. Larson, Chemist, Witco Chemical Co., Inc., Chicago, Ill., and Siegfried Meinstein, Chemist, Witco Chemical Co., Inc., Chicago, Ill.

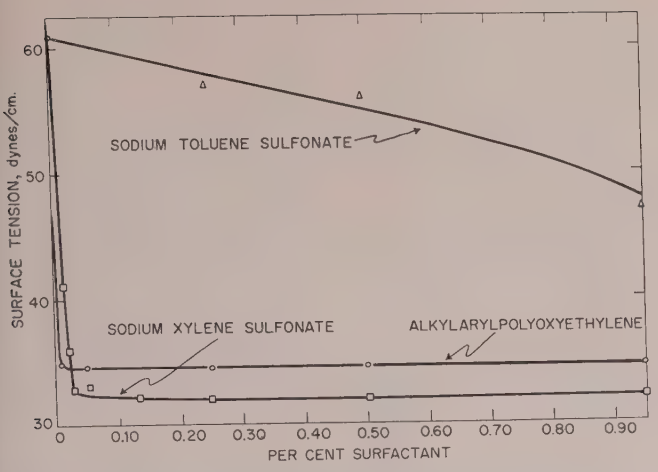

Fig. 1. Surface tension reduction of a 4.0% NaOH solution as a function of surfactant concentration

sumed in the chemical process of digesting) could be recovered and used again without recourse to special techniques.

In other pulping processes, such ready recovery of surfactants does not appear to be feasible. In the kraft process, the spent liquors are concentrated and ignited to recover the inorganic pulping chemicals during combustion of all organic components. Spent soda liquor is treated in a somewhat similar fashion. Therefore, in both processes, surfactants would be nonrecoverable by any economical means. Similarly, in the sulfite and neutral sulfite semichemical processes, spent liquor is not re-used, and practical separation and recovery of a surfactant is not possible.

Since these economic considerations and the relatively slow rate of penetration of alkaline solutions into wood caused selection of the cold caustic process in which to try use of a surfactant, the next step was to choose the most suitable one for this purpose. This choice was quickly narrowed to several from the seemingly hundreds of different types available. Adverse foaming and solubility characteristics in the caustic liquor, as well as prohibitive cost, eliminated most of the commercially available surface-active agents. Lack of effectiveness in reducing surface tensions significantly in alkaline media caused us to discard others. In this manner, the field of possibly useful surfactants was narrowed to several, of which sodium xylene sulfonate (SXS) made by the Witco Chemical Co., and sodium toluene sulfonate appeared to show promise.

Surface tension measurements of these chemicals in water showed that these values were too high to indicate much surface activity in dilute solutions. In strong electrolytic aqueous solutions, however, such as 4% sodium hydroxide, the surface tension values were decreased enormously even at very dilute surfactant concentration. Figure 1 shows this decrease very clearly, particularly in the case of SXS and alkyl-aryl polyoxyethylene. The latter, however, is a typical foam-producing nonionic type.

A limited investigation in the use of anionic and nonionic surface-active agents in the cold caustic pulping of hardwoods has been made by Brown (*1*). Specific surfactants used in this work are not mentioned in his publication. His results showed that addition of 1% surfactant to the liquor increased the penetration in airdry, 1-in. cubes of wood by 50% during 2 hr. of atmospheric steeping, whereas blocks containing 35% moisture picked up liquor 30% faster. Generally, Brown found that surfactants accelerate the penetration of liquor into low moisture-content wood, but show little or no effect on the permeation of green wood. He further concludes that slight increases in brightness and strength properties of the pulp can be realized, and washing operations may be aided in improving the color of cold soda pulp by employing surfactants.

EXPERIMENTAL

Preliminary, small-scale, laboratory experiments indicated tht cold alkaline pulping of aspenwood chips with SXS in the liquor appeared to show greater fiber separation with less loss in strength. More elaborate experiments were conducted to (1) check these observations, (2) note any yield increase, (3) possibly to study power requirements, (4) to study the consumption of SXS in the digesting process, and (5) to determine the optimum concentration of SXS, and caustic.

One of the paper mills, currently manufacturing high yield pulp from aspen, produces wood chips with an average size of $^1/_4$ to $^1/_3$ in. thick and 1 to $1^3/_4$ in. long. One thousand pounds of these chips in airdry condition were obtained for these experiments.

A steel drum with a replaceable top was found that held 50 lb. of airdry aspenwood chips. Caustic soda solution was added to these chips at a ration of 3 lb liquor to 1 of wood. Then the top was bolted on, and the drum was rolled on the floor for 2 hr. to carry out the digestion process. At the end of 2 hr., the liquor was drained from the wood chips, and the chips were passed through the Bauer laboratory refiner, with the residual treating solution adhering to the chips.

Power requirement determinations failed to reveal a clear picture, because the refiner was hand-fed rather than automatically fed under pressure. This intermittent feeding was no doubt responsible for the variance in some results. It is regrettable that, at times, the same power requirements were read for a sample that disintegrated easily as for one which offered more resistance. However, in all cases, the chips treated with a combination of caustic and SXS defibered more readily than did those treated similarly, but without SXS.

At a subsequent plant scale trial run, power savings of 30% at the expeller could be realized. Power consumption at the refiners showed little change. This, of course, is in conformity with expectations, since any power savings at the refiners might well indicate poorer pulp quality.

To obtain more reliable information on defibering a different method of treatment was devised. The chips were treated in two quart jars tumbled continuously while tied to the spokes of a bicycle wheel. All the chips were run through the refiner repeatedly until the same condition of defibering resulted. By this method, the ones treated with SXS always showed faster defibering. It can be said without question that SXS in the digesting liquor aids defibering.

The digestions were carried out at 25°C. for a total of 2 hr. in each case. At the end of the digesting period. the caustic liquors were drained, the jars were filled with cold water four times and drained thoroughly after each refilling to wash out as much of the unreacted caustic as possible. All the wash water was added to the

Table I. Basic Data on Beater Curves for Strength

Unbleached Commercial Kraft				
Freeness, ml.	673	561	480	400
Bursting strength, points	42.5	62.5	63.5	66.8
Tear resistance, g.	102	90	76	74
Folding endurance, double folds	440	1190	1490	890
Bleached Commercial Kraft				
Freeness, ml.	735	468	314	147
Bursting strength, points	6.2	46.4	51.6	51.1
Tear resistance, g.	90	109	93	75
Folding endurance, double folds	5	510	677	870
Unbleached Commercial Sulfite				
Freeness, ml.	690	432	293	166
Bursting strength, points	5.6	28.5	33.4	37.8
Tear resistance, g.	54	55	45	49
Folding endurance, double folds	2	52	94	230
Bleached Commercial Sulfite				
Freeness, ml.	736	486	271	131
Bursting strength, points	4.6	30.4	35.9	41.0
Tear resistance, g.	50	50	35	32
Folding endurance, double folds	1	92	277	345
Bleached Hardwood Soda				
Freeness, ml.	585	531	424	364
Bursting strength, points	2.6	8.4	15.3	23.0
Tear resistance, g.	20	26	34	35
Folding endurance, double folds	1	2	5	7
Commercial Neutral Sulfite				
Freeness, ml.	744	614	396	150
Bursting strength, points	1.6	11.6	25.4	21.8
Tear resistance, g.	22	37	37	33
Folding endurance, double folds	0	4	25	73
Experimental 4% Caustic Steep with 1% MD-106				
Freeness, ml.	450	332	193	89
Bursting strength, points	8.8	16.3	19.8	25.6
Tear resistance, g.	34	36	32	28
Folding endurance, double folds	8	31	87	138
Experimental 5% Caustic Steep				
Freeness, ml.	494	370	219	156
Bursting strength, points	16.6	20.9	27.7	32.7
Tear resistance, g.	21	30	42	34
Folding endurance, double folds	11	26	107	254
Experimental 4% Caustic Steep				
Freeness, ml.	632	520	397	284
Bursting strength, points	8.8	16.3	19.8	25.6
Tear resistance, g.	40	47	38	39
Folding endurance, double folds	4	16	40	45
Experimental 6% Caustic Steep				
Freeness, ml.	545	430	297	166
Bursting strength, points	13.0	18.8	25.4	31.6
Tear resistance, g.	50	55	51	51
Folding endurance, double folds	6	13	51	155
Experimental 6% Caustic Steep with 1% MD-106				
Freeness, ml.	556	485	327	197
Bursting strength, points	11.8	14.2	19.6	25.9
Tear resistance, g.	56	58	55	55
Folding endurance, double folds	5	7	16	41
Experimental 5% Caustic with 1% MD-106				
Freeness, ml.	491	367	201	108
Bursting strength, points	14.5	21.5	27.1	32.0
Tear resistance, g.	58	52	47	38
Folding endurance, double folds	9	20	102	394
Experimental 5% Caustic Steep with 0.5% MD-106				
Freeness, ml.	642	534	311	177
Bursting strength, points	11.5	14.5	25.3	31.2
Tear resistance, g.	33	38	32	31
Folding endurance, double folds	4	8	41	121
Experimental 5% Caustic Steep with 0.25% MD-106				
Freeness, ml.	578	427	283	162
Bursting strength, points	12.5	19.8	27.0	31.8
Tear resistance, g.	33	33	30	30
Folding endurance, double folds	7	27	52	144
Experimental 5% Caustic with 1% MD-106 Recycled				
First cycle				
Freeness, ml.	476	333	199	100
Bursting strength, points	18.1	25.2	30.0	35.2
Tear resistance, g.	38	41	35	30
Folding endurance, double folds	14	38	101	237
Second cycle				
Freeness, ml.	545	389	249	129
Bursting strength, points	13.8	18.4	24.6	29.7
Tear resistance, g.	39	36	35	31
Folding endurance, double folds	5	17	36	86
Third cycle				
Freeness, ml.	505	364	224	121
Bursting strength, points	16.8	22.7	27.5	31.8
Tear resistance, g.	35	30	30	25
Folding endurance, double folds	18	35	104	176
Fourth cycle				
Freeness, ml.	578	423	277	136
Bursting strength, points	12.6	20.7	26.0	31.1
Tear resistance, g.	33	32	30	27
Folding endurance, double folds	13	56	115	235

recovered caustic solution. After proper mixing, titration of an aliquot with standardized hydrochloric acid permitted calculation of the caustic used up.

To determine the consumption of SXS, samples before and after digestion were analyzed in a Beckman DU spectrophotometer at a wavelength of 223 mμ.

This was done by preparing about 10^{-4}molar solutions of surfactant from the pulping liquors, by diluting 1 volume of liquor, both, the fresh and spent, with 500 volumes, each of distilled water. A control sample devoid of any SXS, but in all other respects like the above diluted samples, was also prepared. Absorbancies of the samples were measured. The absorbancy of the control liquor was subtracted from that of the liquors containing SXS to obtain the absorbancy due to SXS. These values varied somewhat between the various fresh and spent liquor samples. But there was no trend, some being higher and some lower than the initial 1.0% content. They were all in the order of magnitude of 1%. Thus, these measurements indicate that SXS was not consumed in the treatment of aspen wood chips. Any loss of SXS in this pulping process would therefore be limited to the amount of original liquor not recovered. This could amount up to 25% or more, depending upon the pulp manufacturing operation.

The yields of the pulps were determined by keeping accurate records of the chips used and the pulps produced. All the figures in this report are given on this basis. It should be kept in mind that these yields are on the wood chips, and not on the original wood. There is a loss up to 5% of wood in the chipping operation.

The refining of 1200-g. samples of chips was done as uniformly as possible. The refiner was set to a load of 3 amp. when empty, but with the required amount of water going through the refiner to carry the chips and pulp along. The chips were put through the Bauer refiner with coarse plates for the initial defibering and then through fine plates for final defibering. Papers from the various pulps were made on the British Sheet Mold.

The strength determinations were made according to Standards TAPPI. All samples were airdried and conditioned at 50% R.H. and 72°F. before testing. Tests for bursting strength, tear resistance, and folding

Table II. Bursting Strength—Points per Pound—Substance 50 (25 × 40—500)

	Freeness, ml. 600	500	400	300	200	100
Unbleached coniferous kraft	1.11	1.28	1.36	1.43	1.51	1.58
Bleached coniferous kraft	0.63	0.88	1.00	1.03	1.04	1.05
Unbleached coniferous sulfite	0.31	0.50	0.60	0.65	0.71	0.76
Bleached coniferous sulfite	0.41	0.58	0.65	0.71	0.77	0.83
Bleached hardwood soda	0.02	0.21	0.39	0.50	0.52	0.54
Hardwood neutral sulfite	0.26	0.41	0.50	0.52	0.48	0.35
Aspen 4% cold caustic	0.21	0.36	0.46	0.50	0.52	0.55
Aspen 5% cold caustic	0.23	0.33	0.43	0.51	0.56	0.59
Aspen 6% cold caustic	0.23	0.31	0.43	0.49	0.59	0.67
Aspen—6% caustic—1% MD-106	0.12	0.25	0.37	0.46	0.52	0.58
Aspen—5% caustic—1% MD-106	0.13	0.27	0.41	0.49	0.55	0.63
Aspen—4% caustic—1% MD-106	0.09	0.25	0.39	0.47	0.54	0.61
Aspen—5% caustic—0.5% MD-106	0.26	0.35	0.43	0.51	0.60	0.68
Aspen—5% caustic—0.25% MD-106	0.24	0.34	0.41	0.51	0.61	0.69
Aspen—5% caustic—1% MD-106 (cycled)	0.18	0.32	0.44	0.54	0.64	0.71
Aspen—5% caustic—1% MD-106 (cycled)	0.19	0.28	0.37	0.46	0.54	0.63
Aspen—5% caustic—1% MD-106 (cycled)	0.26	0.34	0.41	0.49	0.57	0.64
Aspen—5% caustic—1% MD-106 (cycled)	0.22	0.33	0.41	0.51	0.56	0.62

endurance were made. Basis weights of the samples were as near substance 50 (25 × 40—500) as possible and were calculated to that exact weight for interpretation of the data obtained.

The following commercial pulps were beaten in the same laboratory beater to give a comparison between the pulps made experimentally and pulps currently on the market: bleached and unbleached kraft, bleached and unbleached sulfite, bleached hardwood soda, and commercial neutral sulfite. These pulps were taken from stock and cannot be traced to the manufacturers.

RESULTS

Table I represents strength properties of all the pulps. Comparisons were made at various freeness levels. In the table, the four columns represent 0, 20, 40, and 60 min. beating in the laboratory beater. It can be seen, that the freeness at 0 beating time in the 4% caustic was 632 as compared with 450 for the same caustic treatment, but containing SXS. It is to be expected, that, if there is very much difference in the refining of the treated wood due to the presence of SXS, it would be found in the lower caustic treatments.

It should be recorded here, that the wood chips treated with caustic soda alone always lost more weight when refining with the fine plates, than did those containing caustic and SXS. There is considerable evidence to support the view that the SXS-treated fiber was less brittle and that there was less fracturing of the fibers and fiber bundles in the refining action. Beater curves also indicated slower drops in Canadian Standard freeness of the SXS-treated fibers.

To make direct comparisons of the various pulps, it was necessary to draw beater graphs from the data in Table I, and to determine from these the strength values of definite freeness levels. The bursting strength of the various pulps is thus treated in Table II. The strengths are given for freeness values in increments of 100. The bursting strengths are listed in points per pound of paper, which is the actual bursting strength divided by 50.

It is not difficult to see that kraft pulp is in a class by itself on a strength basis. Even though cold soda pulp will never compete with kraft, it is very interesting to make quantitative comparisons. Its relationship to sulfite pulp is more favorable, and it is better than hardwood soda, as well as hardwood neutral sulfite. The latter seems to develop strength faster, but falls short of the total strength attained by the cold soda.

As for the cold soda pulps themselves, there is some indication, that those made with caustic alone develop strength somewhat faster than do those treated with caustic and SXS. When the treatments with 5% caustic soda are considered by themselves, all those in which SXS was used developed more strength at the end of the beating cycle than those with caustic soda alone. The smaller amounts of SXS shows the highest strength values, but very little difference is seen between the two lower ones. On the average, the pulps treated

Table III. Tearing Strength—Grams per Pound—Substance 50 (25 × 40—500)

	Freeness, ml. 600	500	400	300	200	100
Unbleached coniferous kraft	1.8	1.7	1.4	1.3	1.2	1.0
Bleached coniferous kraft	2.2	2.2	2.0	1.8	1.6	1.4
Unbleached coniferous sulfite	1.2	1.2	1.2	1.0	0.9	0.7
Bleached coniferous sulfite	0.9	0.9	0.9	0.9	0.9	0.7
Bleached hardwood soda	0.2	0.3	0.6	0.7	0.7	0.5
Hardwood neutraul sulfite	0.7	0.8	0.8	0.7	0.7	0.7
Aspen 4% cold caustic	0.8	0.9	0.9	0.8	0.6	0.4
Aspen 5% cold caustic	0.3	0.4	0.6	0.7	0.8	0.7
Aspen 6% cold caustic	0.9	1.0	1.1	1.0	0.9	0.8
Aspen 6% cold caustic—1% MD-106	1.0	1.2	1.2	1.1	1.1	1.0
Aspen 5% cold caustic—1% MD-106	1.0	1.1	1.2	1.1	0.9	0.7
Aspen 4% cold caustic—1% MD-106	0.4	0.6	0.7	0.7	0.7	0.5
Aspen 5% cold caustic—0.5% MD-106	0.6	0.8	0.8	0.7	0.6	0.5
Aspen 5% cold caustic—0.25% MD-106	0.6	0.8	0.8	0.7	0.6	0.5
Aspen 5% cold caustic—1% MD-106 (cycled)	0.5	0.7	0.8	0.8	0.7	0.6
Aspen 5% cold caustic—1% MD-106 (cycled)	0.7	0.8	0.8	0.8	0.7	0.6
Aspen 5% cold caustic—1% MD-106 (cycled)	0.5	0.7	0.8	0.7	0.6	0.5
Aspen 5% cold caustic—1% MD-106 (cycled)	0.6	0.7	0.7	0.6	0.7	0.4

Table IV. Folding Endurance—Double MIT Folds on Substance 50 (25 × 40—500) Paper

	Freeness, ml. 600	500	400	300	200	100
Aspen 4% caustic	10	28	44	48	50	50
Aspen 5% caustic	8	13	25	60	140	240
Aspen 6% caustic	7	11	24	54	119	226
Aspen 4% caustic—1% MD-106	..	4	20	44	72	132
Aspen 5% caustic—1% MD-106	..	8	19	50	110	308
Aspen 6% caustic—1% MD-106	..	8	13	22	46	100

with cycled digesting liquors, in which the latter were used over and over for four digestions (with SXS and caustic soda replenished to obtain the composition of the original liquor), showed that this can be done without any reduction in strength of the product.

To be on the conservative side, one must conclude that the cold soda pulps with and without SXS are very nearly alike, according to experimental results. If there is any difference, it is in favor of the SXS-treated pulps. However, the latter enjoy other advantages.

Bursting strength is but one of the tests made on papers in routine analyses. The same type of calculations were made for tear resistance, which are shown in Table III. A close inspection of this table again shows the superiority of the kraft pulps. Almost all other observations in this table clearly indicate the high tear resistance, which can be obtained with the cold caustic pulps. In this respect the ones treated with SXS show a distinct improvement over those digested with caustic only. For some reason or other, the pulps made in the recycling experiments did not develop quite as much tear resistance as those treated with fresh liquors. But since the initial run in the recycling series was not as high as were the previous ones, it cannot be inferred that recycling of the liquors affects tear resistance adversely. In any event, the cold soda pulps are as good and better than the neutral sulfite ones, which are their greatest competitor.

The folding endurance was calculated in a similar fashion, and is recorded in Table IV. From these results, it may be concluded that folding endurance in the pulps made with SXS, develops more slowly than in those digested without SXS. However, the SXS-treated pulps definitely attain higher folding endurance. This is another indication that the fibers in the SXS-treated pulps are more flexible. With 4% caustic alone, the fiber was very brittle. The caustic treatments improve the flexibility as the concentration of caustic is increased. When SXS is used with the caustic, the 6% caustic treated pulps show that the digestion has gone too far maintain folding endurance.

Table V. Pulp Yields and Caustic Consumption

	Yield, %	Caustic consumption, %
4% Caustic	87.5	7.43
5% Caustic	86.2	7.84
6% Caustic	66.4	7.05
4% Caustic—1% MD-106	89.0	7.82
5% Caustic—1% MD-106	95.2	7.54
6% Caustic—1% MD-106	74.5	5.78
5% Caustic—1% MD-106 cycled	87.8	8.18
5% Caustic—1% MD-106 cycled	96.5	9.23
5% Caustic—1% MD-106 cycled	92.4	8.28
5% Caustic—1% MD-106 cycled	86.6	7.34
5% Caustic—0.5% MD-106	86.0	8.20
5% Caustic—0.25% MD-106	89.4	7.84

Table VI. Averages of Pulp Yields and Caustic Consumption

Pulping liquor	Yield, %	Caustic used
Caustic soda alone	80.0	7.44
Caustic plus 1% MD-106	86.2	7.05
Caustic plus 0.5% MD-106	86.0	8.20
Caustic plus 0.25% MD-106	89.4	7.84
Caustic plus 1% MD-106 cycled	90.8	8.25

This is one indication that digestion is accelerated by SXS or penetration of caustic into the wood chips is facilitated, thus enabling the caustic to work more effectively. Whatever the mechanism, the advantages are obvious. Use of SXS might even permit reduction of the digestion time or of the caustic concentration.

The foregoing data show that cold soda pulps have a place in the industry, and use of SXS in the pulping liquor shows some merits in this process. The biggest advantage, however, for SXS is shown in pulp yields, as listed in Table V.

There is no doubt that the use of SXS gives higher yields in the cold caustic process. This should prove of interest to anyone making cold soda pulp. When averages are taken for the different groups in Table V, the values in Table VI are obtained.

Laboratory data are insufficient to permit preparation of a precise production cost analysis for a plant-scale operation, using SXS. This is due to the inability to determine precisely in the laboratory the liquor loss during expelling and disk refining. Obviously, with a group of expellers in series, and countercurrent at each expeller, recovery of SXS will be higher than with only one expeller and one washing. Also, as may be inferred from previous citations, power savings at the expellers would rise commensurately with the number of expellers used on any run.

However, a fair estimate of the cost of using SXS commercially can be made by a scheme described herewith. Sufficient expeller washes are combined with the drained spent liquor from the same batch to make the volume equal to that used initially in the digesting process.

The excess expeller wash water is discarded. Analysis of this combined, retained liquid is then made for SXS content by ultraviolet light spectrophotometry. On the basis of SXS recovered, a cost analysis can be made as follows:

Credit:

Explanatory: yield of o.d. pulp—ovendry pulp expressed in lb. per lb. of dry wood.

$$\frac{(\text{lb. SXS added} - \text{lb SXS recovered}) \text{ price of lb.}}{(1\text{-fraction } H_2O \text{ in wood}) \times \text{yield of o.d. pulp}} = \text{cost of SXS per ton of o.d. pulp}$$

tons of green wood

Debit:

Present pulp cost (o.d. pulp) − [1/(1 + tons extra yield) × present pulp cost] = cost saving from higher pulp yield per ton o.d. pulp.

Gain = debit − credit

This cost analysis, of course, does not take into consideration any other values derived from the use of SXS in cold soda pulping (including any power savings at the expellers). Figure 2 shows the relationship between SXS loss and change in pulping costs. Values

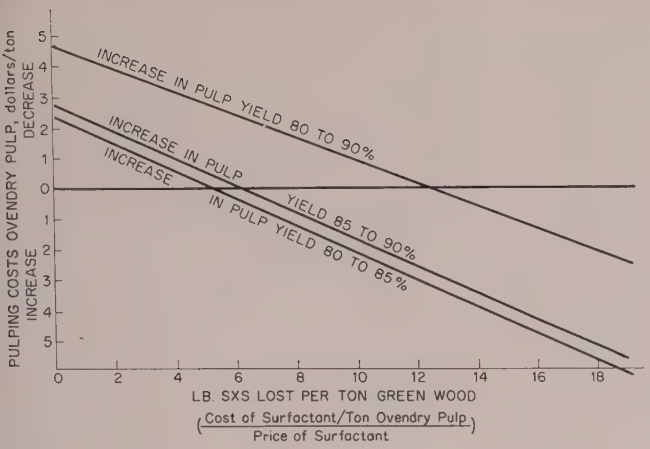
PULPING COSTS OVENDRY PULP, dollars/ton
DECREASE
INCREASE
INCREASE IN PULP YIELD 80 TO 90%
INCREASE IN PULP YIELD 85 TO 90%
INCREASE IN PULP YIELD 80 TO 85%
LB. SXS LOST PER TON GREEN WOOD
(Cost of Surfactant/Ton Ovendry Pulp / Price of Surfactant)

Fig. 2. Pulping cost change per ton of dry pulp with various SXS processing losses

were derived from the above equations using a pulping cost of $51.66 per ton of oven dried pulp (*2*).

Only preliminary experiments were carried out on bleaching the pulps in question. These trials indicated, that they are not more difficult to bleach than other high yield pulps.

CONCLUSIONS

In examining the work and results, one might criticize some of the data, because all of the runs were not made in triplicate. However, having performed the determinations in series overcame some of these shortcomings. Rather definite conclusions may be summarized from all of the foregoing data. These are:

1. The use of SXS with caustic soda gives a softer fiber and requires less power at the expellers than do chips treated with caustic alone.
2. Bursting strength and folding endurance develop as beating is prolonged, and do not diminish as the freeness drops to 100.
3. Pulps made with SXS and caustic are slightly stronger than those made with caustic alone.
4. Pulps made with SXS and caustic can compete with neutral sulfite pulps on a quality basis.
5. The use of SXS with caustic improves the yield noticeably.
6. Pulps made with SXS and caustic are bleachable.
7. Caustic liquor with SXS can be recycled, and SXS is not consumed in the digestion process.
8. SXS pulps defiber faster and more easily.
9. Somewhat improved strength characteristics, combined with an increased yield would tend to indicate better fiber separation, with less damage to and attrition of fibers, when SXS is used in the caustic liquor.

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Oxidation of Kraft Black Liquor with Pure Oxygen

R. E. FONES and J. E. SAPP

Oxidation of southern kraft black liquor with air has met with little success commercially mainly because of the marked foaming tendency of southern kraft black liquor. In this study, oxidation of black liquor in a pressure vessel with pure oxygen was investigated as a possible means of circumventing some of the problems attending the oxidation of southern kraft black liquor. The rate of oxidation of black liquor at elevated temperature and pressure was found to be quite rapid. The changes in concentration of sodium sulfide, sodium sulfate, sodium thiosulfate, and sodium sulfite were determined as oxidation of the black liquor proceeded. The addition of oxygen at the end of a normal kraft cook successfully reduced the sodium sulfide content of the liquor but oxygen consumption was high and a significant reduction in pulp strength and brightness was apparent. The cost of oxidation with pure oxygen was found to be prohibitive in the case studied. However, further decrease in the price of oxygen would make the process economically feasible and worthy of further consideration as a means of oxidizing southern kraft black liquor.

There are several advantages resulting from the oxidation of black liquor from a kraft cooking process. Many authors have cited its usefulness in reducing kraft mill odors. In addition to reducing kraft mill odors, black liquor oxidation reduces corrosion in the evaporators (*1*) and minimizes the loss of sulfur compounds in the recovery process (*2*).

There are two general schemes for oxidizing kraft black liquor. In one system (*3*) air is bubbled through black liquor to form a foam which is broken in a foam breaker. In the other system air is passed up a packed column countercurrent to the flow of black liquor. In the latter system (*4*) the packing is designed to prevent foaming of the black liquor. As far as the authors are aware, attempts to use either system on southern kraft liquor on a commercial scale have been unsuccessful because of the marked foaming tendency of southern kraft black liquor.

Since the cost of tonnage oxygen has decreased over the past decade to a point where it is relatively cheap, a precursory investigation using pure (99.5%) oxygen for oxidizing black liquor seemed worth while. By using pure oxygen the foaming problem would be eliminated since the oxygen would be consumed in oxidation of the black liquor and there would be no inert nitrogen present to support a stable foam. The cost of oxygen in an oxidation system using pure oxygen

R. E. Fones, Technical Assistant in the Sulfate Mill, J. E. Sapp, Assistant General Superintendent, Gaylord Container Corp., Div., of Crown Zellerbach Corp., Bogalusa, La.

Table I. Pulp Cooking Conditions

	Pulp cook no. 1	2	3
Wt. of dry pulp chg., kg.	1.5	1.5	1.5
Water in digester chg., l.	49.1	49.1	49.1
Sodium carbonate in digester chr., g.	100	100	100
Length of cook, min.	210	94	160
pH at blow	8.5	8.8	10.15
Vol. of oxygen injected, cu. ft. at 70°F., 1 atm.	14	13	0
Minimum cooking pressure, p.s.i.g.	100	100	106
Maximum cooking pressure after oxygen addition, p.s.i.g.	125	125	106
Time to pressure, min.	35	35	35

would have to be offset by savings resulting from decreased additions of sulfur.

Oxidation with pure oxygen could probably be carried out in packed towers or foam producing systems with good results. However, addition of oxygen to the digester at the end of a normal kraft cook seemed to offer several advantages as follows: (1) oxidation of liquor in the digester would minimize sulfur losses during the blow; (2) the high temperature in the digester would greatly increase the rate of reaction; (3) there may be an improvement in pulp color; and (4) there would be no large expenditure for oxidation equipment.

Table II. Results of Tests on Pulps

	Original pulp	Cook no. 1	Cook no. 2	Cook no. 3
TAPPI permanganate no.	32.0	5.0	10.0	27.9
Lignin, %	6.99	0.40	1.88	4.73
Brightness, photovolt, %	20.0	46.0	29.0	20.5

Several possible disadvantages of oxidation were recognized as follows: (1) the consumption of oxygen might be high due to the high sulfide concentration in the digester; (2) the digester corrosion rate would probably increase; and (3) pulp strength might be adversely affected.

The objective of the experimental work was to test the feasibility of oxidizing black liquor with pure oxygen either after separation from the pulp or just prior to blowing at the end of a normal kraft cook.

EXPERIMENTAL

The experimental program was divided into three phases: (1) oxidation of pulp alone, (2) oxidation of black liquor alone, and (3) oxidation of pulp and black liquor at the end of a normal kraft cook. All cooks were carried out in the laboratory experimental digester. Each phase of the experiment is described under separate headings below.

Provision for injecting oxygen into the digester was made by connecting an oxygen cylinder to the liquor recirculation line from the digester. The piping to the oxygen cylinder included a needle valve, a check valve, and a trap.

Oxidation of Pulp Alone

In order to determine the pulp strength loss which might be expected upon oxidation at the end of a normal kraft cook preliminary cooks in which pulp alone was oxidized were made. Two samples of normal kraft pulp buffered in a sodium carbonate solution were cooked in an oxygen atmosphere. A third sample of normal kraft pulp buffered in a sodium carbonate solution was cooked without the addition of oxygen. The cooking conditions are given in Table I.

The three cooked pulps and the original pulp were tested for lignin content, TAPPI permanganate number, and brightness. The results of these tests are given in Table II.

The unoxidized pulp (cook no. 3) showed relatively little change in brightness, lignin content, and permanganate number.

The oxidized pulps showed a marked decrease in TAPPI permanganate number and lignin content and a marked increase in brightness compared to the original pulp.

From these data it would appear that an increase in pulp brightness and decrease in lignin content might be expected upon oxidation of black liquor at the end of a normal kraft cook. Other experiments described later in this paper proved that the pulp darkens and the lignin content increases when black liquor is oxidized in the presence of pulp.

The original pulp and the three cooked pulps were beaten and handsheets were made and tested for physical strength. The results are presented in Table III.

All three cooked pulps were easier to beat than the original pulp. The oxidized pulps were very easily beaten. Pulp from the cook where no oxygen was added (cook no. 3) had slightly better strength properties than the original pulp when compared at equal freeness. The drastically oxidized pulp (cook no. 1) had very poor strength compared to the original pulp. The pulp which was not as drastically oxidized (cook no. 2) had much better strength properties than the drastically oxidized pulp but was still definitely lower in strength than the original pulp. The strength increase from cook no. 1 to cook no. 2 was quite marked indicating that oxidation for short periods of time would produce only a slight decrease in pulp strength.

Oxidation of Black Liquor Alone

A sample of black liquor was obtained from the kraft mill blow lines in such a manner as to minimize exposure to atmospheric oxygen. The sampling point and sampling procedure were chosen to obtain a sample of black liquor representative of that in contact with the pulp at the end of a normal kraft cook.

Table III. Physical Strength of Handsheets

Beating time, min.	Original pulp			Cook no. 1			Cook no. 2			Cook no. 3		
	Freeness C.S., ml.	Burst %	Tear %	Freeness C.S., ml.	Burst %	Tear %	Freeness C.S., ml.	Burst %	Tear %	Freeness C.S., ml.	Burst %	Tear %
0	736	58.5	498	741	60	406	714	74	444	729	65	570
5	730	89	434	715	90	267	683	106	342	...	...	...
10	724	101	386	644	104	236	636	120	311	703	108	398
20	700	126	345	482	119	198	431	136	259	649	132	342
35	580	133	302	106	130	166	131	151	222	487	145	310
50	344	143	264	...	...	...	...	...	...	250	153	301

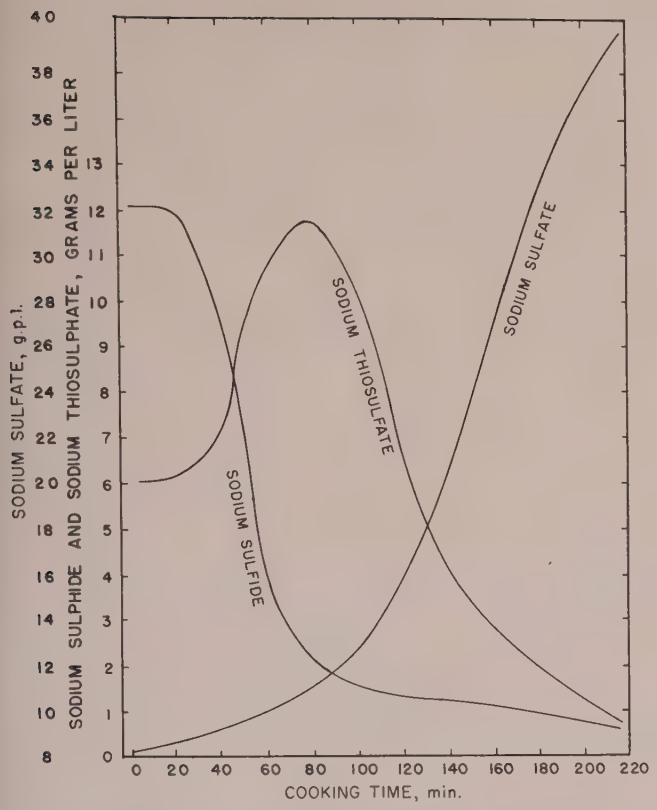

Fig. 1. Change in concentration of sodium sulfide, sodium thiosulfate, and sodium sulfate upon oxidation

Twelve gallons of black liquor were placed in the digester. The pressure was raised as rapidly as possible, using indirect heating. The noncondensable gases were removed by gas-off while the digester was being brought up to pressure.

After the digester reached 100 p.s.i.g., the temperature was held constant and oxygen was injected in sufficient quantity to raise the digester pressure to 120 p.s.i.g. To inject the oxygen into the digester it was necessary to shut off the liquor recirculating pump as well as the valve in the recirculating line ahead of the pump. Earlier attempts at injecting oxygen with the recirculating pump on were unsuccessful because the pump became air-bound and liquor circulation ceased. The pressure regulator on the oxygen cylinder was set at about 300 p.s.i.g. and oxygen was admitted to the digester gradually by controlling the flow with a needle valve. Oxygen thus admitted entered the bottom of the digester and bubbled up through the digester contents, in this case black liquor. After the oxygen had been injected to raise the digester pressure to 120 p.s.i.

Table IV. Analysis of Oxidized Black Liquor

Time after steam, min.	*Total oxygen added, cu. ft. at 70°F., 1 atm.*	*Sodium sulfide, g./l.*	*Sodium sulfate, g./l.*	*Sodium thio-sulfate, g./l.*	*pH*
0	0	12.1	8.2	6.1	11.78
27	0	11.4	9.0	6.3	11.70
38	7.0	7.6	9.6	6.0	11.61
45	7.0	8.3	10.0	7.5	11.55
55	12.0	5.4	10.9	10.1	11.46
62	12.0	4.3	10.0	10.6	11.41
78	21.0	2.0	10.5	11.8	11.15
95	29.0	1.8	11.9	10.7	10.61
114	42.0	1.3	16.7	7.8	9.91
150	63.0	1.1	23.9	3.1	9.16
191	68.0	0.8	35.5	1.5	8.72
217	74.0	0.5	39.5	0.5	8.56

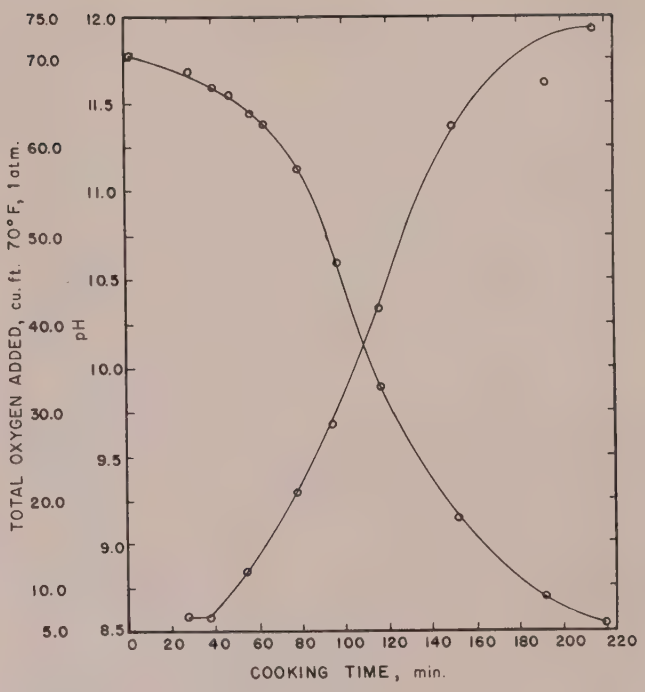

Fig. 2. Oxygen addition and pH as a function of cooking time

the recirculating valve was opened and the liquor recirculating pump was started.

The digester pressure was allowed to fall to 100 p.s.i. after the oxygen injection before more oxygen was injected. In all, oxygen was injected 15 times in the 3 hr. and 40 min. cook. The rate and schedule of oxygen addition are given in Table IV and Fig. 2.

One-quart samples of black liquor were taken at the times indicated in Table IV. These samples were analyzed for sodium sulfide, sodium sulfate, sodium sulfite, sodium thiosulfate, and pH. TAPPI Method T 625 m-48 was used in analyzing for all black liquor components except sodium sulfide. In the latter case, a modification of the TAPPI Method suggested by Collins (*5*) was used. In this modification 40 ml. of 12.5% NH_4Cl was added instead of adjusting the pH to 4.0 with normal acid.

The results of the tests are given in Table IV and Figs. 1 and 2. Since the test for sodium sulfite was negative in every case, these results are not included in Table IV.

From the data it can be seen that the sodium sulfide reacts rapidly with the oxygen initially injected into the digester to form mainly sodium thiosulfate. The sodium thiosulfate concentration builds rapidly to a maximum after which the sodium thiosulfate is further oxidized to form sodium sulfate. The odor of the samples withdrawn for testing became less characteristic of a kraft cook as the oxidation proceeded.

The cost of reducing the sodium sulfide content of black liquor from 12.1 to 2.0 g.p.l. with pure oxygen was calculated from the data in Figs. 1 and 2. Since the cost of oxygen depends on the demand, the amount of black liquor oxidized was assumed to be that equivalent to 1000 tons per day of pulp production. The cost of the oxygen required to carry out the oxidation would be approximately $579 per day in this case. Assuming that sulfur additions are made at the rate of about 22 lb. per ton of pulp to maintain the sulfidity

Table V. Cooking Conditions for Pine Chip Cooks

Cook no.	102	103
Total wt. of chip chg., o.d.,[a] g.	4000	4000
White liquor added, l.	7.56	7.56
Liquor/wood ratio	4.0:1	4.0:1
Active alkali in white liquor, g./l. as Na_2O	99.0	99.0
Active alkali chg., %	18.7	18.7
Gas-off schedule—up to pressure, ml.	420	420
Gas-off schedule—at pressure, ml.	140	140
Time up to pressure, min.	70	70
Total cooking time, min.	140	140
Oxygen added 15 min. before blow	No	Yes
Total oxygen added, cu. ft. at 70° F., 1 atm.	0	21

[a] o.d. = ovendry.

before oxidation and that no sulfur additions are necessary after oxidation, the saving in sulfur cost was calculated to be about $300 per day.

The above cost of oxidation was based on oxidation of black liquor with a high sodium sulfide content. In commercial practice it is normal to oxidize the weak black liquor from the washing operation. Exposure of

Table VI. Results of Tests on Pulps

	Cook no. 102	*Cook no. 103*
TAPPI permanganate no.	27.2	32.8
Lignin, %	4.37	5.21
Brightness, photovolt, %	26.0	18.0
Screened yield, %	44.7	45.1
Rejects, %	0.90	0.93

the black liquor to air, especially on the washers, markedly decreases the sodium sulfide content of the liquor (*2*, *6*). No studies have been made by the authors to determine the concentration of sodium sulfide in the weak liquor; however, the literature indicates that liquor with an original sodium sulfide content of about 12 g.p.l. would contain no more

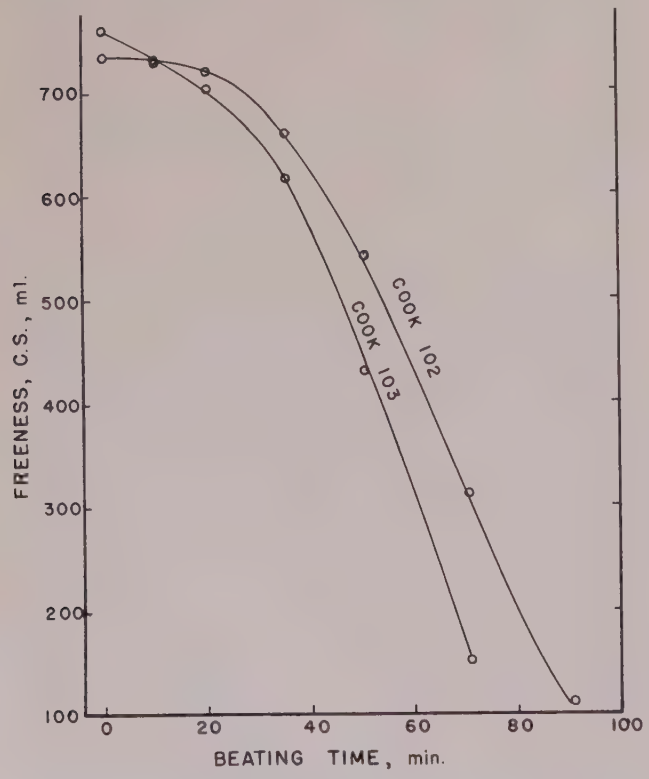

Fig. 3. Beating characteristics of normal kraft and oxidized pulps

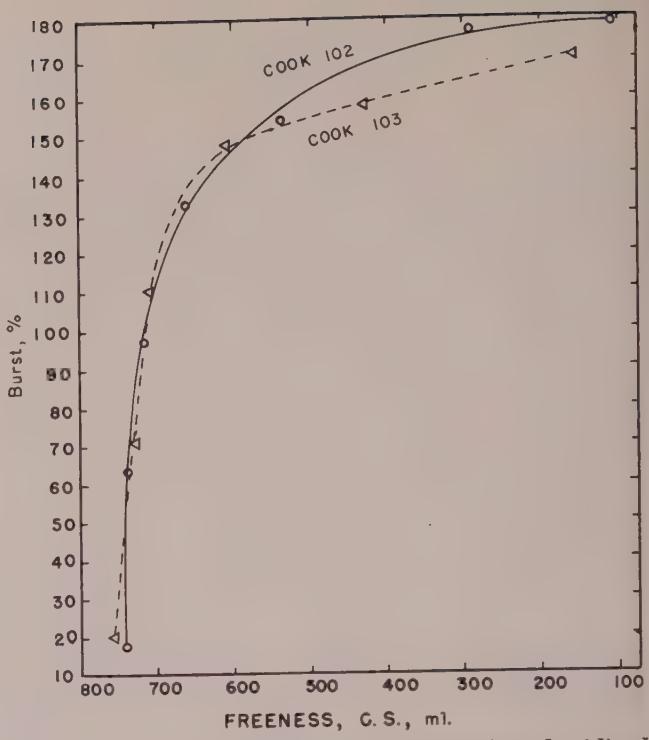

Fig. 4. Comparison of burst on normal kraft and oxidized kraft pulps

than about 7 g.p.l. after passing through the washers.

The cost of oxidation using pure oxygen was calculated for reducing the sodium sulfide content from 7.0 to 2.0 g.p.l. using the data on oxygen consumption from Figs. 1 and 2. The cost in this case was $536 per day for 1000 tons of production.

The cost calculations presented above indicate that oxidation of black liquor with pure oxygen is too expensive for most present-day applications. There may be some mills in which justification can be partially based on odor control and/or alleviation of stream pollution. Since the price of oxygen decreases with increasing demand, justification would be easier in large tonnage mills. At some future date, however, further advances in the technology of making oxygen may reduce its price to a point where consideration on a broader scale would be warranted.

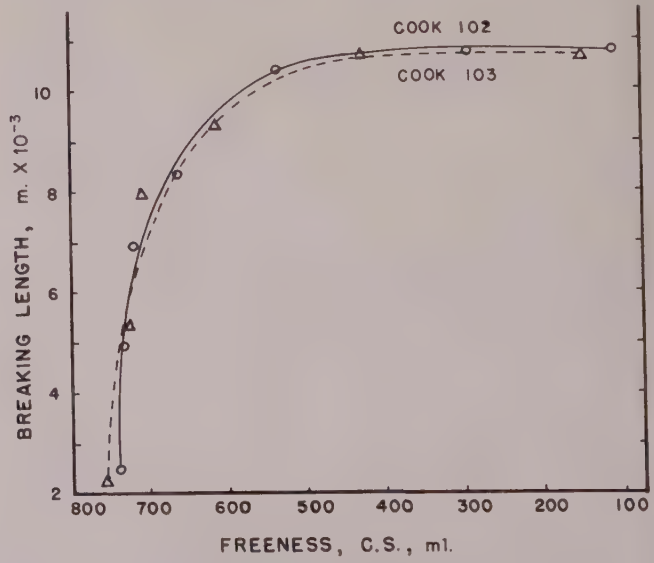

Fig. 5. Comparison of breaking length on normal kraft and oxidized pulps

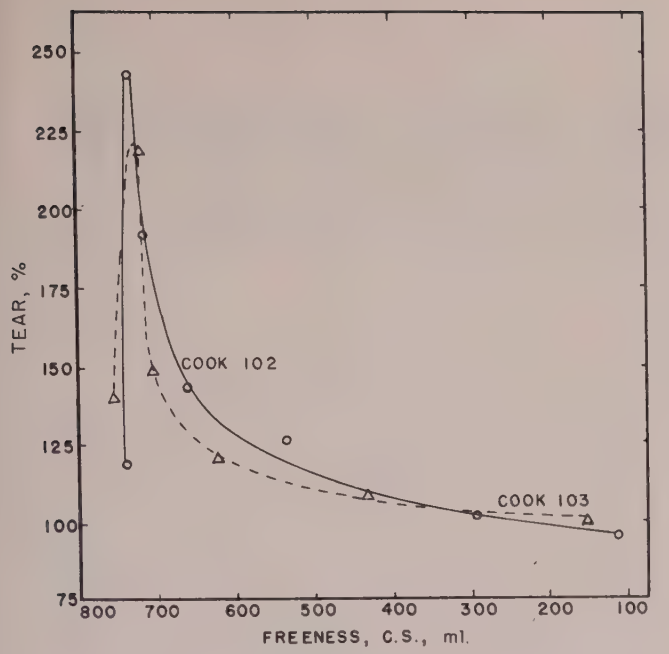

Fig. 6. Comparison of tear on normal kraft and oxidized kraft pulps

Oxidation of Pulp and Black Liquor at the End of a Normal Kraft Cook

Two normal kraft cooks were made in the experimental digester under the same conditions with the exception that oxygen was injected before the end of one cook. Cook no. 102 was the normal kraft cook made as a control while cook no. 103 had oxygen added 15 min. before the end of the cook. The cooking conditions are given in Table V and the results of some of the tests on the pulp are given in Table VI.

Table VII

	White liquor	*Cook no. 102 Normal kraft black liquor*	*Cook no. 103 Oxidized kraft black liquor*
Sodium sulfide, g./l.	45.4	11.4	1.4
Sodium thiosulfate, g./l.	8.6	2.3	2.2
Sodium sulfate, g./l.	14.8	7.4	22.4
Sodium sulfite, g./l.	2.9	0	0

From the data in these tables it can be seen that the cook in which oxygen was used produced a pulp with a higher lignin content and permanganate number and a lower brightness. These findings are contrary to the results of the experiments in which pulp alone was oxidized. This is probably due to the fact that the sodium sulfide in the liquor is converted to sodium thiosulfate and sodium sulfate thereby lowering the content of active cooking chemical. Although the pH of the liquor at the end of cook no. 103 was not checked, it was probably reduced as indicated from the data on oxidation of black liquor alone. This reduction in pH would slow the pulping reaction and account for the harder pulp obtained in the cook where oxygen was added.

Beating curves were obtained for each of the cooked pulps. Although the pulp from the cook in which oxygen was added was a "harder" pulp, Fig. 3 shows that this pulp was easier beating than the normal kraft pulp.

Handsheets were made from the beaten pulp and their strength properties were evaluated. The results are presented in Figs. 4 through 6. These data show that the two pulps are about equal in breaking length and tear when compared at equal freeness. The burst on the oxidized pulp was lower than that on the unoxidized pulp.

Samples of the white liquor, normal kraft black liquor, and oxidized black liquor were analyzed for sodium sulfide, sodium thiosulfate, sodium sulfate, and sodium sulfite. The results are presented in Table VII.

It is apparent from these data that the conditions imposed in cook no. 103 resulted in almost complete oxidation of the black liquor. The high oxygen consumption reported in Table V is probably due to the fact that both the pulp and the liquor consumed oxygen with the liquor being oxidized almost completely. The rate of reaction found at the end of a normal kraft cook was faster than the rate of reaction found in the oxidation of black liquor alone, probably because the pulp present greatly improves the efficiency of contacting between the gas and liquid phases in a manner similar to packing in a packed column.

The cost of oxygen required to oxidize the liquor from 1000 tons of pulp per day from 11.4 to 1.4 g.p.l. was calculated. The high oxygen consumption resulted in the high cost of $1100 per day.

From the results of the experiment in which black liquor was oxidized at the end of a normal kraft cook it must be concluded that oxidation in the digester is impractical. The high cost of oxygen alone would make the process unjustifiable. In addition, pulp strength and brightness were adversely affected.

CONCLUSIONS

Oxidation of black liquor at the end of a normal kraft cook is too costly at present oxygen prices. In addition, the pulp strength and color are adversely affected by oxidation in the presence of black liquor.

The cost of oxidation of black liquor taken from the digester was found to be high partly because of the high sodium sulfide content in the digester. Oxidation of weak black liquor with a lower sodium sulfide content would reduce the cost of oxidation to some extent.

Economic justification for using pure oxygen would be simpler for the larger mills since the cost of oxygen decreases with increasing demand. Southern mills faced with problems of odor abatement, high evaporator corrosion rate or high lime costs, would have added justification for oxidation of black liquor with pure oxygen.

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Effect of Volatile and Moisture Content on Electrical Properties of Phenolic Resin Paper Laminates

MYER EZRIN and STUART H. RIDER

Small amounts of moisture absorbed by resin-treated paper before laminating is the primary factor determining the 60-cycle dielectric properties of the resulting laminate. The effect of absorbed moisture is far greater than that of a comparable amount of water released as water of condensation on curing the resin. Measurements have been made of the 60-cycle dielectric properties of resin-impregnated paper and of unimpregnated paper as a function of absorbed moisture content in the uncured, oven-cured, and press-cured states. These data indicate that the large increase in dissipation factor resulting from moisture absorption is due to association between the absorbed water and cellulose during press-curing. On the other hand, water of condensation released on curing is associated with resin primarily, thus moderating its effect on electrical properties.

Pretreatment of paper with a small amount of a low molecular weight melamine—or phenol—formaldehyde resin prior to impregnation with resin substantially prevents moisture absorption by the paper resulting in improved electrical properties. Electrical properties other than those at 60 cycles, particularly after water immersion, are also improved as a result of the pretreatment of the paper. When melamine resin is used, the fire resistance is also improved appreciably.

A CONSIDERABLE amount of work has been reported by several investigators during the last two decades dealing with various aspects of the effect of water on the properties of phenolic laminates. Hartshorn, Rushton, and Megson (*1*) studied the effect of water absorbed by paper laminates on dielectric properties. Croup (*2*) reported on the effect of moisture absorbed by impregnated paper on the physical properties of paper base laminates. Cox and Pepper (*3*) made a similar study which dealt with the effect of volatile substances on mechanical properties. Dakin and Auxier (*4*) measured the effect of absorbed moisture on the dielectric properties of paper and fabric and of paper and fabric impregnated with phenolic resin.

In the present study, the effect of volatile matter on electrical properties of phenolic paper laminates has been studied in two ways. First, the volatile content as a function of time in the drying oven was used. In the second case, the volatile content was varied by allowing dried, impregnated paper to absorb atmospheric moisture prior to laminating. The latter effect was studied using paper which had no special treatment prior to impregnation with phenolic varnish. Dielectric properties at 60 cycles were measured to determine these effects because of the greater sensitivity to the presence of water at the low frequency (*1*). The study was made using cresol-formaldehyde varnish and an aniline modified cresol-formaldehyde varnish.

MYER EZRIN and STUART H. RIDER, Research Department, Monsanto Chemical Co., Plastics Division, Springfield, Mass.

EFFECT OF DRYING TIME

The volatile content as a function of drying time was varied by first drying resin impregnated, 0.007-in. rag paper containing 50% resin, for a short time at 120°C. The paper was then further dried for varying lengths of time at 120°C. to obtain the desired range of volatile content. The laminates were pressed immediately after removal of the paper from the drying oven in order to eliminate atmospheric moisture as a variable. A press cycle of 20 min. at 150°C. and 1000 p.s.i. was used; the laminates were approximately $^1/_{16}$ in. thick. Volatile content determinations were made at the time of pressing using the per cent loss in weight after 10 min. at 160°C. The dissipation factor and dielectric constant at 60 cycles were determined for each laminate after being exposed to a conditioning period of 6 days at 23°C. and 50% R.H. The properties were determined again after the laminates had been immersed in water at 23°C. for 24 hr. (D/24/23). The measurements were made according to ASTM Method D 150–47 T using a Schering Bridge.

The reproducibility of the data was demonstrated by repeating the experiments for both resins. Values at the same volatile content could be reproduced within 0.001 dissipation factor, and the curve determined by one set of data was able to predict reasonably well the values to be obtained from the other set.

The results are shown graphically in Fig. 1 for the cresol varnish and in Fig. 2 for the aniline modified cresol varnish. The dissipation factor before water immersion is increased only slightly as the volatile content increases. This result would not necessarily have been predicted considering the great sensitivity of 60 cycle dielectric properties to the presence of water.

The rate of increase of dissipation factor is greater for the cresol resin than for the aniline modified, cresol varnish. In both cases, the slope of the dissipation factor curve after water immersion is very nearly the same as the slope before water immersion. This is an indication that the per cent water absorption, which, in effect, determines the increase in dissipation factor due to the water, is independent of volatile content.

MEASUREMENTS AT ZERO VOLATILE CONTENT

Sixty cycle dielectric properties of a cresol-resin-paper combination were measured at zero volatile content in order to confirm the values obtained by extrapolation to zero volatile content, and also, to determine the best possible values obtainable with such a combination. In this experiment, 0.010 in. alpha-cellulose was impregnated with cresol resin to a resin content of approximately 50%, and dried for a short time at 120°C. as in the experiment described above, and then dried

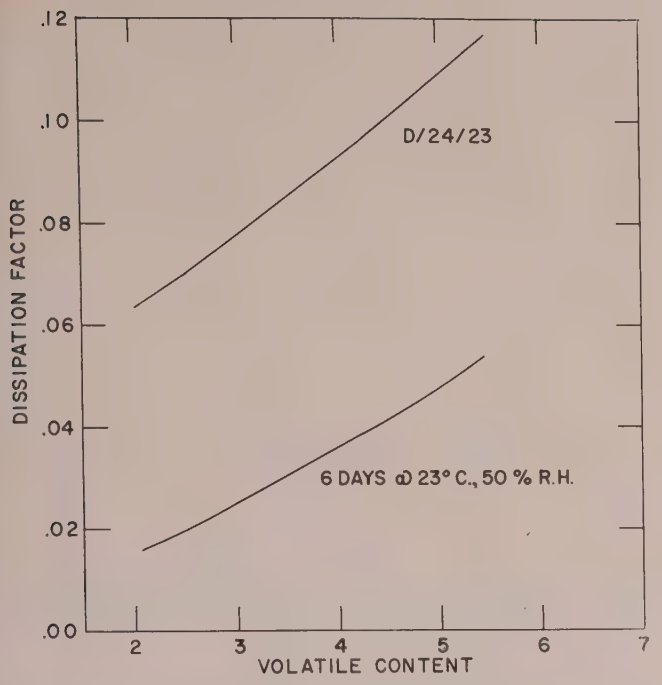

Fig. 1. Dissipation factor at 60~ vs. volatile content of cresol resin laminate

further for varying lengths of time so as to give a series approaching zero volatile content. In addition, some impregnated sheets were cured in an air-circulating oven at 150°C. for 20 min. (same as the press cycle, but no pressure). The volatile matter, which is trapped in a laminate cured under pressure, was thus allowed to escape, giving cured sheets with essentially zero volatile content.

The electrical properties at zero volatile content were obtained by assembling the same number of sheets as in a laminate, and painting electrodes with silver paint in the usual manner on the top and bottom sheets. A large weighted metal electrode (4 in. diameter) was used in the Schering bridge electrode system to effect close contact between the sheets of the zero volatile layup during testing. The data are plotted in Fig. 3. A dissipation factor of 0.003 at 60 cycles was obtained at

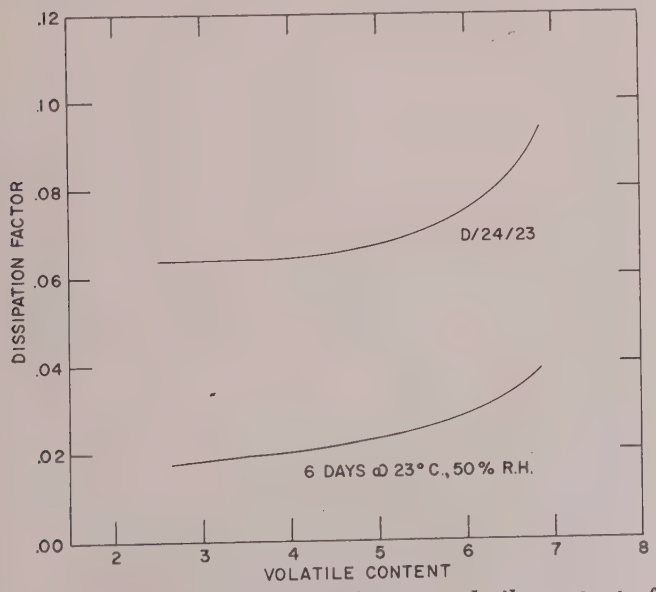

Fig. 2. Dissipation factor at 60~ vs. volatile content of aniline modified cresol resin laminate

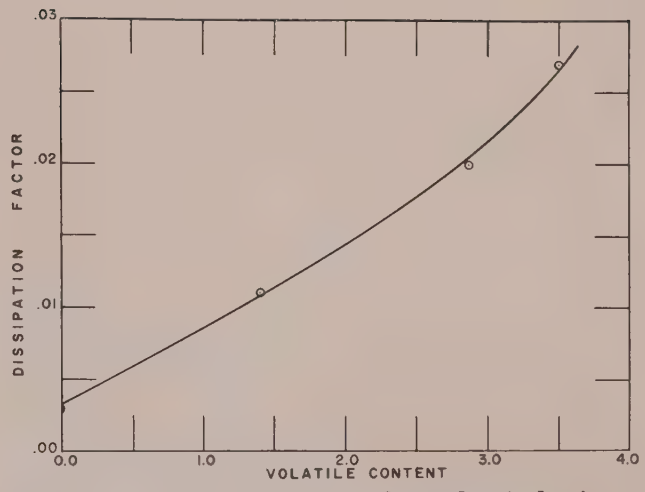

Fig. 3. 60~ dissipation factor of cresol resin laminates measured at and extrapolated to zero volatile content

zero volatile content, in excellent agreement with the value obtained by extrapolation.

Reasonable values of dielectric constant could not be obtained with the above arrangement, presumably because of the presence of air. A value of 1.88 was obtained, compared to an extrapolated value of between 3.5 and 4.0.

NATURE OF THE VOLATILE MATTER

The volatile content is reported by Cox and Pepper (*3*) to consist of approximately 50% water. This has been confirmed in the present study by curing impregnated paper in boiling xylene (141°C.) and collecting the water given off in a Dean-Stark azeotropic distillation receiver (*5*). The other 50% must be solvent (alcohol) and low molecular weight resin. The amount of water originally present in the treated paper, as it is removed from the drying oven, before final curing, was determined by the Karl Fischer method (*6*). The difference between the two test results gave the water of condensation released in the curing process. The Karl Fischer result is a composite of residual solvent water, residual water associated with the cellulose, water of condensation released during curing in the drying oven but not completely driven off, and moisture absorbed from the atmosphere following removal from the oven.

The data are presented in Table I. The water of condensation is determined as the difference between the Dean-Stark water content and the Fischer water content. The water of condensation accounts for approximately 62% of the water present in the volatile matter. The several other possible sources of water referred to above account for the difference of approximately 38%, but it is not possible, from the data, to determine the amount of water contributed by each of the sources.

ABSORBED MOISTURE

Effect of Moisture Absorbed Prior to Pressing

The effect of atmospheric moisture absorbed by impregnated paper prior to pressing into a laminate was evaluated in the following manner. Rag paper, 0.007 in., was impregnated to a resin content of 52 to 53% and dried in the usual manner to a volatile content suitable for laminating. A portion of the treated paper was pressed immediately using the same press cycle de-

Table I. Volatile and Water Content of Paper and Cresol Resin Impregnated Paper

	Paper[a]	*Resin-paper*[b]
Volatile content, 10 min. at 160°C., %	3.80	4.79
Volatile content, 20 min. at 160°C., %	4.38	5.06
Karl Fischer water content, %	5.44	0.90, 0.95
Dean-Stark water content, %	5.10	2.44, 2.43
Water of condensation, %	..	1.54, 1.48

[a] Hurlbut 521 alpha-cellulose, 0.010 in. thick.
[b] Resin content 48.9%, dried 9 min. at 122°C.

scribed previously, and the volatile content was determined simultaneously. The remainder of the paper was allowed to absorb atmospheric moisture by suspending it in a room, the atmosphere of which was maintained constant at a temperature of 23°C. and 50% R.H. Portions of the paper were removed at various times. The laminates were prepared immediately on removal from the controlled atmosphere, and the volatile content determined simultaneously. The laminates were tested for 60 cycle dielectric properties using the same conditions as described previously, i.e., after 6 days at 23°C. and 50% R.H., then after immersion in water 24 hr. at 23°C.

The data are presented in Table II for both of the resins studied. Two effects are outstanding. The first is the very great increase in dissipation factor resulting from the absorption of relatively small quantities of moisture. The second is the increasing dissipation factor drift (increase in dissipation factor after water immersion of the laminate) with increasing moisture pickup by the treated paper.

In Fig. 4 are plotted the data presented in Table II for the cresol varnish, combined with data which were obtained for the same resin in the experiment in which the effect of volatile content as a function of drying time alone was studied. The curves make strikingly clear the magnitude of the effect of moisture absorbed from the atmosphere on the 60-cycle dissipation factor. The difference is still very great if correction is made in the comparison for the fact that only approximately 50% of the volatile content (in the absence of atmospheric moisture) represents water of condensation and water not removed in the drying oven. The increase in dissipation factor drift with increasing absorption of moisture can also be seen in Fig. 4.

It seems clear, then, that free water absorbed from the atmosphere prior to laminating has a profoundly greater effect on electrical properties than does an ap-

Table II. Effect of Moisture Absorption by Impregnated Paper before Pressing on Dissipation Factor of Laminates

Time at 50% R.H. before press., hr.	*Volatile content 10 min. at 160°C., %*	*60-Cycle dissipation factor* Condition 1[a]	Condition 2[a]	*Dissipation factor drift*[b]
Aniline Modified Cresol Resin Laminates				
0	5.46	0.042	0.078	0.036
1	6.02	0.093	0.163	0.070
17	6.71	0.332	0.469	0.137
24 3/4	7.16	0.335	0.477	0.142
Cresol Resin Laminates				
0	4.03	0.037	0.099	0.062
3/4	4.45	0.069	0.136	0.067
1 3/4	4.57	0.089	0.167	0.078
18 1/4	5.51	0.266	0.436	0.170

[a] Condition 1 = Laminate conditioned 6 days at 23°C. and 50% R.H. Condition 2 = Laminate immersed in water 24 hr. at 23°C. following condition 1.
[b] Increase in dissipation factor after water immersion.

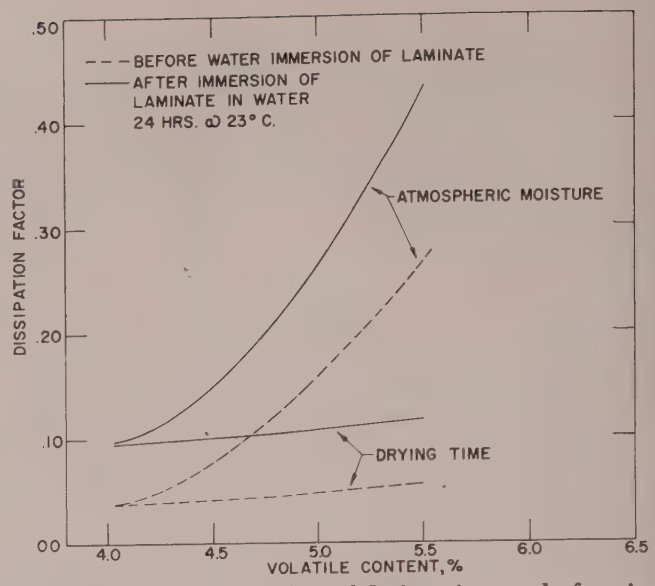

Fig. 4. Comparison of effect of drying time and of moisture absorbed by impregnated paper on 60~ dissipation factor of cresol resin laminates

proximately comparable amount of water which is normally present in the volatile matter, most of which is liberated in the laminate due to the thermosetting reaction. Undoubtedly the paper is largely responsible for the moisture which is absorbed from the atmosphere since it is far more hydrophilic than the resin. While it is true that the presence of the resin retards the moisture pickup, the impregnation of the paper by the resin is never sufficient to eliminate the effect completely.

Because of the much more hydrophilic nature of the cellulose compared to the resin, the water molecules, for the most part, became associated with the former by means of weak physical forces, such as that exerted by hydrogen bonding. The bonding of these water molecules to the cellulose molecules of the paper is probably strong enough so that the water molecules are not disrupted by the pressing operation. Thus they are left in the laminate as essentially free water associated with cellulose by weak forces, without being intimately surrounded by the phenolic resin molecules. On the other hand, the water of condensation which is released during the pressing operation is completely surrounded by a network structure of the resin molecules.

The same is also essentially true of the other water originally present. Even though the water may have been associated originally with the cellulose (paper alone had a water content of 5.44%), it is brought into intimate association with the resin via the alcohol solvent, and is "trapped" as the resin becomes highly cross-linked during the pressing operation. Consequently the mobility of the water molecules is restricted, with the result that the effect on electrical properties is moderated. A comparable restriction on molecular motion does not exist in the case of the water absorbed from the atmosphere.

Effect of Absorbed Moisture on Dissipation Factor of Impregnated Paper Before and After Pressing

The following experiments were performed in order to obtain experimental evidence for the cellulose-water association theory postulated above.

The dissipation factor of a layup of uncured alpha-cellulose sheets impregnated with cresol resin, which had

been allowed to absorb moisture, was determined in the same manner as that described already for cured sheets. The data are given in Table III for various amounts of moisture absorbed.

After humidity conditioning for 24 hr. the layup of impregnated sheets minus the silver-painted electrode sheets, were laminated in the press 20 min. at 150°C. and 1000 p.s.i. The resultant laminate was found to have a dissipation factor of 0.514.

Table III. Effect of Absorbed Moisture on Dissipation Factor of Unimpregnated Paper and Cresol Resin Impregnated Paper

Time at 50% R.H. before press., hr.	*Volatile content 10 min. at 160°C., %*	*Karl Fischer water content, %*	*60-Cycle dissipation factor Before pressing*	*60-Cycle dissipation factor After pressing at 150°C. 1000 p.s.i.*
		Paper		
0	3.16	4.49	0.087	...
2	5.04	6.08	0.327	...
5	4.67	6.06	0.357	...
24	4.95	6.65	0.363	0.011
		Uncured Resin-Paper		
0	4.39	0.52	0.011	...
2	4.67	1.07	0.023	...
5	4.94	1.53	0.035	...
24	5.95	2.50	0.061	0.514
		Oven-Cured Resin-Paper		
0	0.00	...	0.003	...
2	1.11	...	0.008	...
5	1.39	...	0.011	...
24	2.27	...	0.028	0.006

Untreated paper (Hurlbut 521 alpha-cellulose) in a similar experiment gave the results also shown in Table III. After pressing for 10 min. at 150°C. and 1000 p.s.i. following 24 hr. at 50% R.H., a dissipation factor of 0.011 was obtained.

Cresol resin-treated alpha cellulose which had been cured at atmospheric pressure (oven) 20 min. at 150°C. gave the results also shown in Table III when exposed to 50% R.H. and subsequently tested. The dissipation factor obtained after pressing the sheets which had been exposed for 24 hr. was 0.006.

The results of these experiments indicate that the influence of absorbed moisture on dissipation factor of resin-treated paper laminate is due to association with cellulose and that the effect is not really felt until the press curing operation. Up to that time, the uncured resin exerts a slight barrier effect on the moisture, preventing it from coming into intimate contact with the cellulose. Under the influence of pressure and heat, however, the water molecules become associated with cellulose very rapidly before sufficient cross-linking of the resin occurs to trap the absorbed moisture within the network structure of the resin. At the same time, the associated water molecules cannot escape, as occurred when the layup of sheets of untreated paper was "cured" under pressure, because of the restraining influence of the rapidly curing resin.

Further evidence for the cellulose-water association theory is found in the results of the series using oven-cured impregnated paper. The absorption of approximately 2% moisture caused an increase in dissipation factor of only 0.025, while the same amount of moisture absorbed by uncured sheets gave a dissipation factor increase of 0.503 on press curing.

Effect of Absorbed Moisture on Dissipation Factor Drift

The increase in dissipation factor drift resulting from absorption of moisture by impregnated paper is undoubtedly associated with an increase in water absorption. This was observed by Croup (*2*) and by Cox and Pepper (*3*) in their studies of the effect of moisture on the physical properties of paper base laminates. Two possible causes for increased water absorption suggest themselves.

The first is hydrolytic degradation of the cellulose under the combined influence of the water and the high temperature used in the pressing operation. The degradation products of the cellulose may be more hydrophilic than the cellulose, with the result that the laminate absorbs more water. The work of several investigators on related problems supports this hypothesis. Clark (*7*) found that the rate of mechanical deterioration of cellulose insulation is greatly accelerated by small amounts of moisture. The mechanical life of the insulation is reduced by one-half for each doubling in water content. In addition, deterioration promoted by oxidation is accelerated by the presence of moisture. In the field of textile research, Bogaty, *et al* (*8*), and Wiegerink (*9*), as well as several others, have reported on various aspects of the increased degradation of cotton in the presence of moisture at high temperatures.

A second possible cause of increased water absorption is associated with a purely physical effect. The absorbed moisture is held in the voids of the cellulose fibers, and reduces the extent of penetration of the resin into the voids during the pressing operation.

It is reasonable to expect that other electrical properties which are particularly sensitive to the presence of water, such as insulation resistance, should be similarly affected by atmospheric moisture absorbed by treated paper. The phenomenon is undoubtedly common to the usual variety of phenolic resin varnishes.

MELAMINE RESIN PRETREATMENT

Effect of Atmospheric Moisture on Impregnated Paper Pretreated with Melamine Resin

The adverse effects of moisture absorbed by impregnated paper are minimized to a considerable extent by impregnating the paper with a small percentage of a low molecular weight, water soluble melamine resin or phenolic resin before treating with the phenolic varnish. Excellent penetration of the paper fibers is assured by using a low molecular weight, water soluble material. In this work 5 to 10% solutions of resin were used, and the resin pickup was 7 to 9% based on the weight of the paper and of the low molecular weight resin. The paper was dried after the first resin treatment in the usual manner for a short time, sufficient to remove the solvent and advance the resin somewhat. The dried paper was then impregnated with phenolic varnish in the usual manner. The resulting laminate thus consisted of a total resin content of approxinately 50%, of which approximately 5% is resin added in the first pass and 45% is the usual phenolic resin.

Data illustrating the magnitude of the effect of the first pass treatment of paper are given in Table IV. Alpha-cellulose paper, 0.010 in., impregnated with the aniline modified cresol resin was used in this experiment. In the bottom half of the table the impregnation with

Table IV. Effect of Melamine Resin Treatment of Paper on Dissipation Factor of Aniline Modified Cresol Resin Laminates

Time at 50% R.H. before press., hr.	*Volatile content 10 min. at 160°C., %*	*60-Cycle dissipation factor Condition 1[a]*	*Condition 2[a]*	*Dissipation factor drift[b]*
Control—No Melamine Resin Treatment				
0	4.86	0.030	0.074	0.044
1	5.86	0.086	0.167	0.081
1 3/4	6.06	0.133	0.226	0.093
19 1/6	6.86	0.208	0.362	0.154
Paper Treated with Melamine Resin Before Impregnation				
0	4.44	0.010	0.040	0.030
2/3	4.83	0.017	0.035	0.018
1 3/4	4.85	0.030	0.061	0.031
17 1/2	5.54	0.085	0.123	0.038

[a] Condition 1 = Laminate conditioned 6 days at 23°C. and 50% R.H. Condition 2 = Laminate immersed in water 24 hr. at 23°C. following Condition 1.
[b] Increase in dissipation factor after water immersion.

varnish was preceded by a treatment with low molecular weight melamine resin. The upper half of the Table is the control portion, in which case no pretreatment was used. The two sets of impregnated paper were exposed to the atmosphere at 23°C. and 50% R.H. The absorption of moisture is reduced as a result of the first pass treatment as seen by the volatile content data. The dissipation factor is affected only slightly compared to the control. The dissipation factor drift is hardly affected by the exposure of the paper to the atmosphere, whereas the drift increases significantly in the case of the paper which was not first treated with melamine resin. In Fig. 5 the data are presented graphically as a function of "time at 50% R.H. before pressing."

As a result of the first pass treatment, the slope of the curve of dissipation factor versus time at 50% R.H. at low exposure times is reduced several fold. The dissipation factor is not affected too seriously even after long exposure time before pressing. The same observations apply to the dissipation factor drift curves.

Table V. Effect of First Pass Treatment of Paper by Low Molecular Weight Melamine or Phenolic Resin on Drift Properties of Cresol Resin Laminates

First-pass resin	*None*	*Melamine resin*		*Phenolic resin*
First-pass resin content, %	0	5	9	9
One MC. D.F. drift D/24/23[a]	0.0051	0.0042	0.0036	0.0016
One MC. D.C. drift D/24/23[b]	0.34	0.29	0.25	0.07
One KC. D.F. drift D/24/23	0.0949	0.0793	0.0465	0.0168
One KC. D.C. drift D/24/23	1.07	0.80	0.56	0.22
I.R., ohms, D/24/23[c]	2.2×10^9	2.8×10^9	1.6×10^{11}	1.1×10^{11}
Water abs., D/24/23, %	1.02	1.09	0.72	0.46

[a] Increase in dissipation factor after immersion of laminate in water 24 hr. at 23°C.
[b] Increase in dielectric constant after immersion of laminate in water 24 hr. at 23°C.
[c] Insulation resistance after immersion of laminate in water 24 hr. at 23°C.

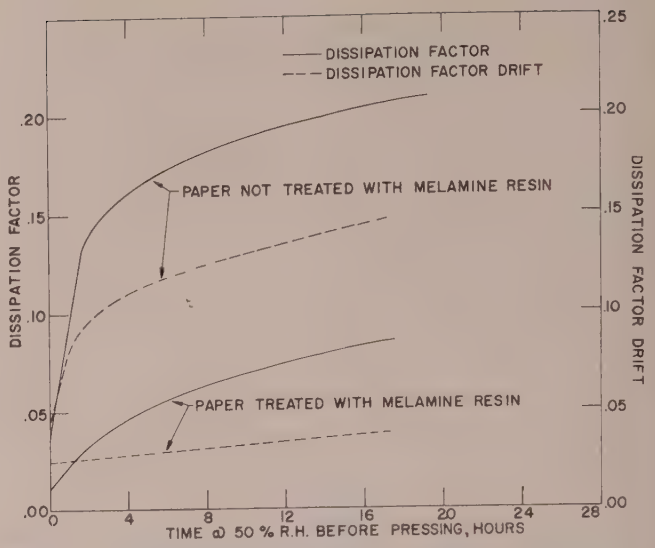

Fig. 5. Effect of melamine resin treatment of paper on 60~ dissipation factor of aniline modified cresol resin laminates

Analysis of the data reveals that these effects resulting from the pretreatment of the paper cannot be explained solely on the basis of decreased rate of moisture absorption. It is believed that the mobility of the water which is absorbed from the atmosphere is reduced considerably due to the cross-linking of the first pass resin when the laminate is pressed. This is reasonable because the low molecular weight nature of the first pass resin and its application from dilute aqueous solution make for intimate association of the resin with the cellulose molecules in much the same manner as the water molecules. The resin and the water thus exist in essentially the same "phase." The result is that in the laminate, after pressing, the water absorbed from the atmosphere is surrounded by a network structure not too different from that which surrounds the molecules of water of condensation of the phenolic resin.

Effect of Melamine Resin Pretreatment on Other Electrical Properties

Electrical properties other than those at 60 cycles are also improved by pretreatment of paper. The main effect is to increase the resistance of the laminate to water and humidity conditioning. In Table V electrical properties at one megacycle and one kilocycle, insulation resistance after water immersion 24 hr. at 23°C. (D/24/23), and water absorption are given for a series of 0.007-in. alpha-cellulose cresol resin laminates. These include (1) melamine resin as the first pass resin at two different resin contents, (2) phenolic resin as the first-pass resin, and (3) a control which had no special treatment.

The improvement in electrical properties after water immersion can be correlated with the improvement in water absorption. The effect is not too great at one megacycle because the electrical properties at the high frequency are not very sensitive to the presence of water. On the other hand, insulation resistance, which is very sensitive to water, is improved by a factor of almost 100 compared to a factor of 2 for the improvement in water absorption.

A first-pass resin content of 5% melamine resin is not sufficient to have a significant effect on properties. The effect at 9%, however, is significant. The com-

parison is most striking in the case of insulation resistance.

Effect of Melamine Resin Pretreatment on Fire Resistance

In addition to the general improvement of electrical properties, the fire resistance of both resin laminates is improved considerably by the first-pass treatment with melamine resins. The improvement is much greater than would result from incorporation of the same amount of melamine resin into the cresol resin. The fire resistance of the aniline-modified cresol resin laminate is upgraded sufficiently to make it self-extinguishing in 10 to 20 sec. after removal of the flame when the test specimen is supported horizontally (ASTM D 635–44). In the absence of melamine resin, the laminate is not self-extinguishing. The after-glow or flameless combustion which often occurs with phenolic laminates after the flame has been extinguished is eliminated completely by the melamine resin treatment.

These experiments indicate that there is a definite advantage gained in fire resistance by impregnating the paper fibers with a fire resistant material. Impregnation of the paper with a low molecular weight, highly penetrating resin from an aqueous solution provides the very best penetration of the fibers that can be obtained. It is for this reason that the adverse effects of moisture absorbed by treated paper are minimized so effectively. The fact that the fire resistance is improved so greatly indicates that the paper is a very important factor determining the fire resistance of paper laminates.

The importance of fiber penetration by the resin as opposed to simply increasing the amounts of resin lying on top of the fibers was shown by the fact that doubling the melamine resin content of the paper from 8 to 16% before impregnation with aniline modified cresol resin caused no further improvement in fire resistance.

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Post Pressure Roll Yankee Drier Sheet Consistency Determination by Material and Enthalpy Balance

WILLIAM A. DICKENS

Two general techniques of post pressure roll Yankee drier sheet consistency determination are presented: the drier hood material balance and the drying system enthalpy balance. Methods of measuring drying hood flows and humidities, necessary for material balance, that have worked well in practice, are presented. The techniques outlined have proved invaluable for Yankee drier system studies.

The accurate measurement of many important paper machine operating variables is often a difficult matter. The reasons are numerous. Sampling techniques often are difficult and likely to cause machine downs. Most operating machines are designed for speed and efficiency of operation and not for ease of testing. Machine conditions are continuously changing, increasing the difficulty of obtaining representative information. Most of these difficulties apply to the determination of sheet consistency immediately after pressure roll application to a Yankee drier.

Sheet consistency to the Yankee drier is a most important variable in creped wadding machine operation as machine speed and hence production is often limited by the drying capacity of the Yankee drier and its associated hood. Thus, the drier the sheet on application to the drier, the greater the production potential of the machine and the more profitable the operation. Therefore, it is obvious that an accurate technique of measuring the post pressure roll water content of a sheet is a valuable tool. If this water content proves to be higher than normal, a program of wet-end and furnish changes can be undertaken to provide easier dewatering prior to the drier. In addition, this consistency value offers a method of determining the amount of dewatering accomplished prior to the drying system by a given change in machine operation.

William A. Dickens, Chemical Engineering Laboratory, Research and Development Division, Kimberly-Clark Corp., Neenah, Wis.

CONSISTENCY DETERMINATION BY HOOD MATERIAL BALANCE

The water content of a sheet immediately after application to a Yankee drier cannot be measured easily or accurately by a direct sampling technique. Therefore, an indirect method must be used. The method described below based on classical material and enthalpy balances, though somewhat time consuming, is capable of good accuracy.

Yankee drier hoods are normally operated so that there is little or no blow out of the hot, humid, drying-system air into the machine room. This means that essentially all the moisture evaporated from the sheet

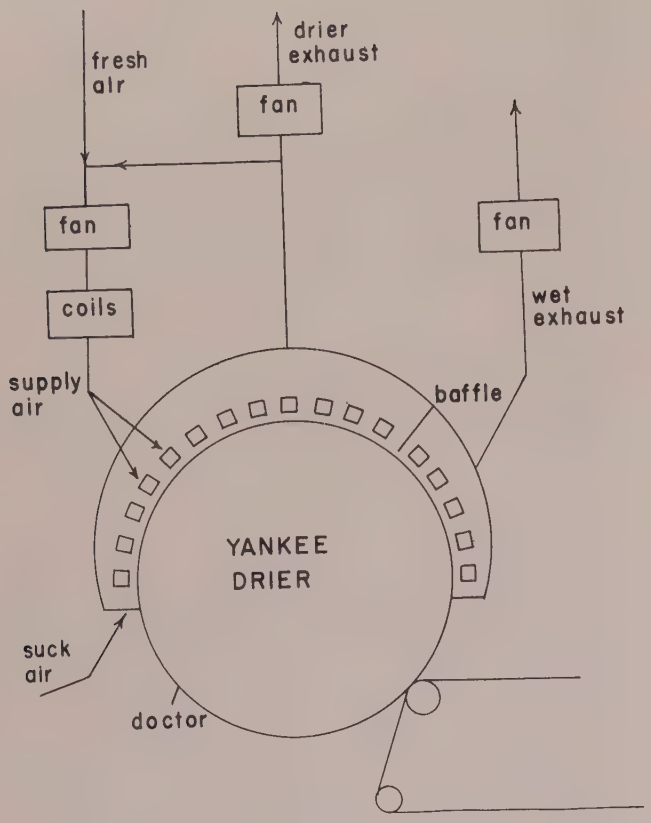

Fig. 1

must leave the drying system via the hood exhausts. This fact is the basis of sheet consistency determination by hood material balance.

The important air-flows in a typical Kimberly-Clark Corp. wadding drying hood are schematically illustrated in Fig. 1.

Heated supply air is directed at the sheet via nozzles from a series of plenum chambers spaced around the drier periphery. The air supplied to the area adjacent to the pressure roll, being the wettest and coldest air, is completely exhausted by the wet exhaust fan. The remainder of the supply air, after contacting the sheet, is split into two streams, one of which is recirculated and mixed with fresh air and heated to form the supply air stream. The remaining fraction is exhausted to the atmosphere as the dry exhaust stream. In addition, there is some suck air into the hood from the machine room. Obviously, all water evaporated from the sheet must leave via the two exhaust streams. If suitable techniques are available to measure the flow and humidity of the dry exhaust, wet exhaust, fresh air, and suck air streams, then the rate of evaporation from the drier surface may be easily calculated by material balance.

This figure, combined with production and roll moisture figures, indicates the sheet water content after application by the pressure roll. Let the important flows and humidities be designated by the following symbols:

H_{WE} = wet exhaust humidity, lb. H_2O/lb. moisture-free air
H_{DE} = dry exhaust humidity, lb. H_2O/lb. moisture-free air
H_{FA} = fresh air humidity, lb. H_2O/lb. moisture-free air
H_{SA} = suck air humidity, lb. H_2O/lb. moisture-free air
F_{WE} = wet exhaust air flow, lb./hr.
F_{DE} = dry exhaust air flow, lb./hr.
F_{FA} = fresh air flow, lb./hr.
F_{SA} = suck air flow, lb./hr.
E = water evaporation from sheet, lb./hr.

Since the hood operates under essentially steady state conditions, the following relations must apply:

$$F_{FA} + F_{SA} = F_{DE} + F_{WE} \quad (1)$$

$$H_{FA} F_{FA} + H_{SA} F_{SA} + E = H_{WE} F_{WE} + H_{DE} F_{DE} \quad (2)$$

Equation (2) indicates the quantities that must be measured if the evaporation from the sheet, E, is to be determined.

FLOW MEASUREMENT

The most difficult job is the measurement of the wet and dry exhaust flow rates. On most production machines, the ductwork is of such a character as to make flow measurement by a conventional pitot tube an arduous task, subject to large inaccuracies. The ductwork usually contains many bends, contractions, and expansions with only short lengths of straight ducting, which situation leads to highly erratic and uneven flow profiles. In addition, flows in some areas are hard to measure accurately because of small velocity heads. The actual flow rates of the exhaust streams are thus difficult to determine by a pitot tube traverse.

The method of exhaust stream air-flow measurement that has proved to be most valuable is an SO_2 dilution technique. This technique consists of introducing sulfur dioxide into the exhaust stream at a known flow rate and analyzing for the concentration of SO_2 at a point downstream of the point of introduction where essentially complete mixing of the SO_2 with the air stream has occurred. Sulfur dioxide has several advantages as a low concentration additive for flow measurement. It is inexpensive, it is comparatively innocuous in the low concentration range (30 to 50 p.p.m.) in which it is employed and a relatively easy analytical technique is available for SO_2 determination in the low concentration range. Other diluents could be used but none of those considered to date possesses the advantages of SO_2.

The SO_2 is metered into the exhaust stream via a sonic orifice. This orifice consists of a small hole drilled through a stainless steel plate at the *vena contracta* of which the SO_2 velocity is the velocity of sound in SO_2. A sonic orifice is an excellent method of metering small quantities of a pressurized gas. Sonic velocity is achieved by maintaining the pressure back of the orifice above the pressure defined by the critical pressure ratio. At constant upstream pressure, the flow through a given sonic orifice is a function only of upstream temperature. As an example, a 0.042-in. orifice gives an SO_2 flow of about 0.1 lb. per min. for 25 p.s.i.g. SO_2 pressure.

After mixing has occurred, the concentration of SO_2 in the air stream is most easily determined by an iodometric technique. For an SO_2 in air concentration of about 50 p.p.m., an absorbing solution which is about 0.001 N with respect to iodine and which contains starch indicator and 40 g. of potassium iodide per liter is an effective absorbing solution. About 10 l. of air are bubbled through a 100-ml. sample. A blank is needed as the hot air tends to volatilize about 2% of the iodine.

To be an effective flow measurement technique, the SO_2 dilution method requires complete mixing of the

SO_2 before sampling and analysis of the air stream. A fan is generally an excellent mixing device. In the analysis of one system, SO_2 was introduced immediately before the exhaust fans and essentially complete mixing prevailed 10 ft. downstream of the fan. In another system, the fan did not accomplish a similar degree of mixing and it was necessary to introduce the SO_2 considerably upstream of the fan to have a reasonably even concentration profile (variation of no more than 2%) for analysis after the fan.

In the analysis of one system, the dry exhaust flow could not be measured by the SO_2 technique because of poor fan mixing and lack of sufficient ductwork prior to the fan. In this case, twelve point addition across the fan was tried without success. Where this is the case, a reasonably accurate pitot tube technique can be devised by suitable minor and temporary ductwork changes. In many instances, the major drawbacks of a pitot tube flow-measurement technique are that the flow profile is highly uneven, because of the character of the ductwork, and that the flow velocity is too low to be measured with the required accuracy. This situation can be cured by constricting the flow through a temporary conduit. The flow area of this conduit is sized to give a reasonably high velocity pressure without unduly restricting flow. The length/diameter ratio of the conduit should be large enough (about 5) to give a fairly even velocity profile. A pitot tube traverse will then give a satisfactory answer.

HUMIDITY MEASUREMENT

The standard method of humidity measurement of air streams is by the wet and dry bulb technique. This method is adequate at room temperature, but becomes progressively more unsatisfactory at more elevated temperatures. At the high temperatures and humidities characteristic of a drying system, serious errors result from the assumption that wet bulb and adiabatic saturation temperatures of air are the same. Therefore, a different method, based on the absorption of water on an efficient desiccant, is considerably more accurate. The technique which we have utilized involves the absorption of the water vapor from a known weight of air on Anhydrone (magnesium perchlorate), an efficient desiccant.

This desiccant may be used at high temperatures because the first hydrate is stable to 278°F. Humidity values are obtained by drawing air samples by oil displacement through a U tube containing the desiccant. Because of the temperature stability of the desiccant, the U tube may be heated prior to sampling to prevent premature condensation in the tube arm.

CONSISTENCY CALCULATION

Having the wet and dry exhaust flows and humidities, the fresh air humidity and the production and roll moisture figures, the calculation of the post pressure roll consistency is a relatively easy matter. By equation (1), the fresh and suck air flows must equal the sum of the wet and dry exhaust flows. Usually, the fresh air flow is the major fraction of the air supply and only a minor error is introduced by assuming that the suck air humidity equals the fresh air humidity (usually it is somewhat higher). If the suck air flow is large and there is an important difference between fresh and suck air humidities, the fresh air flow may be measured by suitably constricting the flow and utilizing a pitot tube traverse. Equation (2) then defines the evaporation, and calculating the consistency is an easy matter.

ENTHALPY BALANCE CHECK

An enthalpy balance is a good technique for checking the consistency value obtained by material balance. An enthalpy balance may be utilized if the flow of steam to the drying system and the enthalpy change this steam undergoes can be easily measured. The following quantities are important terms in an enthalpy balance:

S	= steam flow to drying system, lb./hr.
ΔH_S	= steam enthalpy change, B.t.u./lb.
E	= water evaporation from sheet, lb./hr.
ΔH_E	= evaporated water enthalpy change, B.t.u./lb.
F_{FA}, F_{SA}, F_{DE}, F_{WE}	= air system flows, lb./hr., previously defined
H_{FA}^*, H_{SA}^*, H_{DE}^*, H_{WE}^*	= fresh air, suck air, dry exhaust, and wet exhaust specific enthalpys, B.t.u./lb.
P	= dry production rate, lb./hr.
ΔH_p	= production enthalpy change, B.t.u./lb.

Using the above defined variables, the following steady state enthalpy balance can be written if we neglect heat losses to the surroundings, and other minor system enthalpy flows:

$$S\Delta H_S = E\Delta H_E + F_{DE}\,H^*_{DE} + F_{WE}H_{WE}^* + P\Delta H_p - F_{FA}H_{FA}^* - F_{SA}H_{SA}^* \quad (3)$$

Steam flow is best measured by calibrated orifice. If the drier condensate and blow through is collected in one or more separators and the flash and blow steam used to heat the supply air, the exit enthalpy of the steam may be considered, with small error, to be that of water at the saturation pressure of the low pressure separator. The pressure and the temperature of the supply steam define the inlet steam enthalpy.

The air flows are measured as previously described. The values of the air specific enthalpy term are solely a function of the temperatures of the individual air streams, which may be easily measured. The value of ΔH_E is determined by the temperature at which the sheet is applied to the drier and the temperature of the exhaust streams. Thus, equation (3) may be easily solved for E. The water evaporation rate and the sheet consistency as it is applied to the drier may be determined from the evaporation rate and production figures. The assumption that the heat losses from the system may be neglected is a good one. The convective heat loss from an insulated hood should be about 1% of the total system heat flow which usually is between 6×10^6 and 20×10^6 B.t.u./hr.

Comparison of equations (2) and (3) shows that an increase in the measured exhaust flows indicates a lower consistency by the material balance and a higher consistency by the enthalpy balance. Thus, good agreement between the consistency values obtained by the two methods lends confidence to the results.

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Water Immersion of Resin-Saturated Paper

FRITZ ROSENTHAL

Numerous quality control problems in the production of paper saturated with phenolic resins pointed to a need for a control method to determine the effectiveness, uniformity and degree of cure of resin-saturated papers. The "Weight Gain Test" which measures the weight gain of specimens of saturated paper after a brief immersion in water before, during, and after resin cure is described; the test follows the transition from a water-absorbent to a water-repellent sheet. The same test method lends itself to the comparison of different phenolic resins and to the study of factors affecting resin condensation.

THE properties of paper can be modified by impregnation with many types of synthetic resins. The oldest of these, phenolformaldehyde, is still the most widely used for this purpose.

The function of the phenolformaldehyde resin as a saturant in paper is based on its capacity to be converted into the insoluble and infusible stage under the influence of heat. This complex chemical reaction, plus the highly developed surface structure of the cellulose fiber, has been primarily responsible for the problems of quality control of these saturated papers. To give only one example for these problems, the determination of the resin content in such papers by solvent extraction becomes increasingly unreliable with storage time, since the solubility of the phenolic resin decreases progressively. Thus, it becomes very difficult to determine whether a sheet of paper has been saturated with the required percentage of resin, or whether the resin has been applied uniformly. Other factors affecting the quality of these saturated papers are moisture content and the degree of resin cure.

A test is described here to determine the effectiveness, uniformity and condition of paper saturated with phenolformaldehyde resin. The test, briefly designated as the weight gain for saturated paper, is based on the weight gain of specimens of saturated paper after a brief immersion in water before, during, and after resin cure; it follows the transition from a water-absorbent to a water-repellent sheet. The test is rapid, reproducible, and has the advantage of not requiring any unusual or expensive laboratory equipment.

METHOD AND PROCEDURE

Strips of phenolic resin-impregnated paper (6 × 1 in.) were weighed airdry to 0.01 g. They were immersed in water of 76°F. for exactly 5 sec. The wet strips were shaken to throw off excess water until water droplets were no longer released, which normally required 25 sec., and were then reweighed. The per cent weight gain was calculated from the two weighings.

Strips of phenolic resin-impregnated paper were weighed airdry and placed between two platens electrically heated to 300°F. for various periods of time. The distance between the platens was chosen as $^1/_8$ in. to facilitate quick insertion and removal of the paper specimens so that the heat exposure times could be kept as precise as possible. These heated strips were immersed in water, and reweighed as described in the previous paragraph.

FRITZ ROSENTHAL, Knowlton Bros., Inc., Watertown, N. Y.

RESULTS AND DISCUSSION

Plots of calculated weight gain after water immersion versus heating time usually have the form of an S-curve (Fig. 1), showing the rate of transition from water absorbency to water repellency. The initial slope of the curve steepens as the specimen approaches the platen temperature and as the cross-linking of the phenolic resin proceeds. The steepest portion of the S-curve depicts the actual curing of there sin. After prolonged heating, the curve flattens and the weight gains finally reach a level which does not change by continued heating.

The S-curve obtained by the transition from water-absorbency to water-repellancy has a striking resemblence to S-curves of the flow rate of phenolic molding powders when subjected to the influence of heat and pressure. These S-curves are obtained on the recording mechanism of the Rossi-Peakes flow tester, which is illustrated and described in ASTM Standard Method D 569-48.

The reproducibility of the weight-gain method is dem-

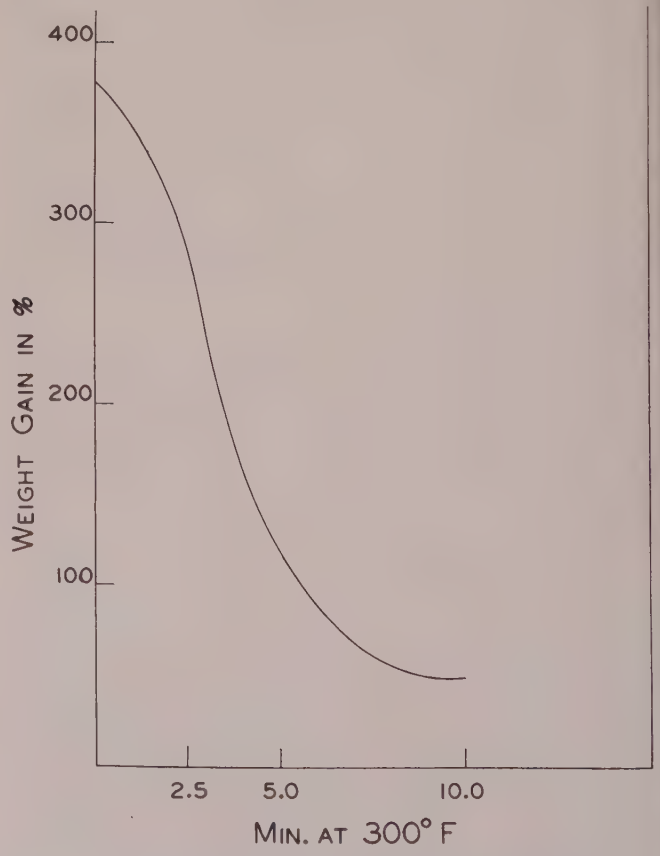


Fig. 1. Typical weight-gain curve of phenolic resin-impregnated paper

Table I. Reproducibility of Weight Gain Results

Experiment	Heating time, min. 0 Gain %	3 Gain %	5 Gain %	10 Gain %
1	386	140	68	57
2	396	134	69	55
3	407	136	83	62
4	369	147	67	63
5	403	161	66	50
6	373	166	63	71
7	362	174	68	53
8	391	131	83	56
9	402	136	72	53
10	404	167	89	57
Average	389	149	73	58
Standard deviation	15.4	15.4	8.4	5.8

onstrated by the data in Table I, showing weight gains after water immersion of phenolic resin-saturated paper heated to 300°F. for 0, 3, 5, and 10 min. The deviations tend to decrease with increasing heating time.

APPLICATIONS OF THE WEIGHT GAIN TEST

Identification of Cause in Defective Saturated Paper

Improper Resin Saturation. The following experiment illustrates the use of the weight-gain test to show that the tested paper was improperly saturated. The cure of this paper was followed by heating specimens cut across the width of the web, their location being marked 1, 2 and 3 to 300°F. for 0, 3, 5, and 10 min. The weight gain data of these specimens were plotted against heating time, as shown in Fig. 2. It is seen from this plot that locations 1 and 2 showed a high water absorption even after prolonged heating to 300°F. This phenomenon indicated the absence of resin in areas of high water pickup after heating. Location 1 showed more lack of resin than location 2. It should be noted that this test is more sensitive than the solvent extraction of phenolic resin; the sensitivity of that procedure decreases with age of the saturated paper sample.

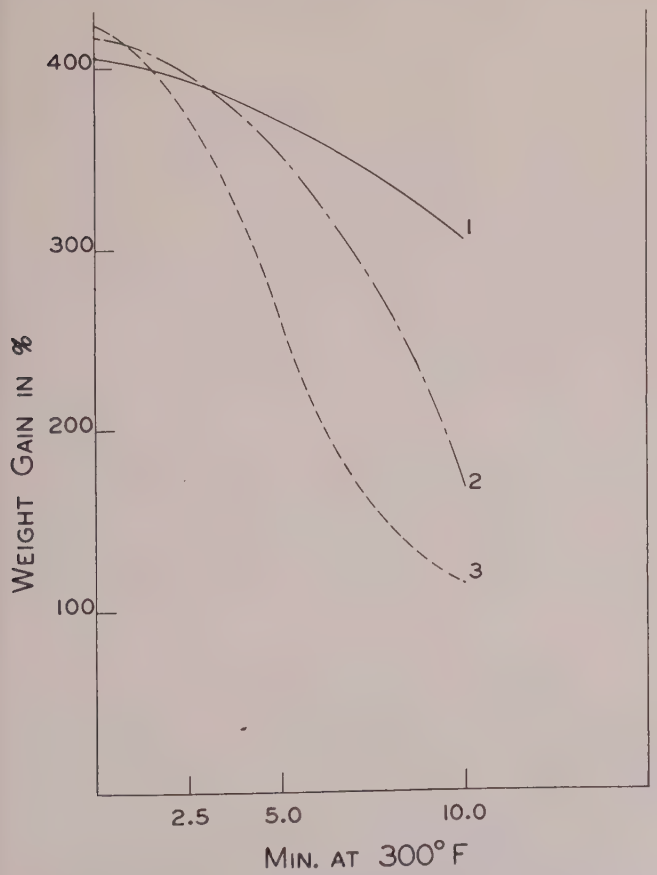


Fig. 2. Weight-gain curve of paper not uniformly saturated with phenolic resin

Moisture Pickup. When damp, resin-saturated paper is subjected to curing temperature, the moisture evaporates causing a heat loss. This heat loss manifests itself in a retardation of cure. This is illustrated in Fig. 3, which shows weight-gain curves of two saturated sheets, one conditioned by storage over anhydrous $CaCl_2$ (curve 1), one over saturated water vapor (100% R.H., curve 2).

It is demonstrated that the weight-gain pattern of damp paper reverts to a pattern approaching that of predried paper by subjecting the damp paper to a vacuum treatment at room temperature which removes the moisture without affecting the cure of the resin; after such a vacuum treatment, curve 3 in Fig. 3 is obtained.

Rolls of paper are sometimes stored so that an outside edge is exposed to moisture. This edge is apt to cure at a slower rate than the dry inner paper. The weight gain after immersion shows this (Fig. 4, curve 1). A similar curve would be obtained if the resin content was low at one edge, as could be the case at improper satura-

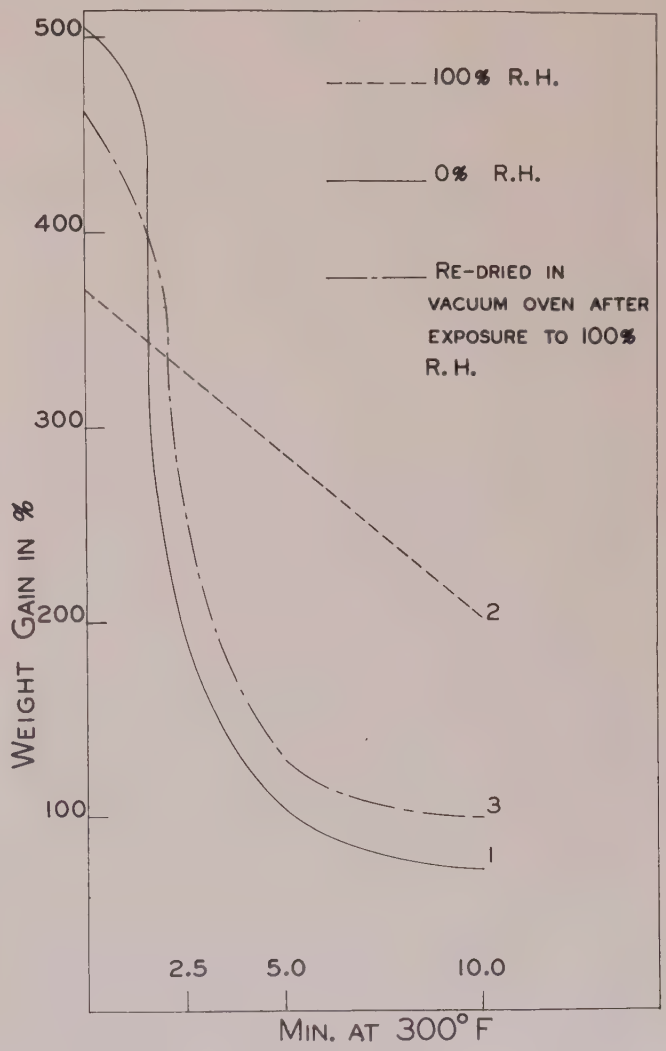


Fig. 3. Effect of exposure to humidity on weight-gain curves

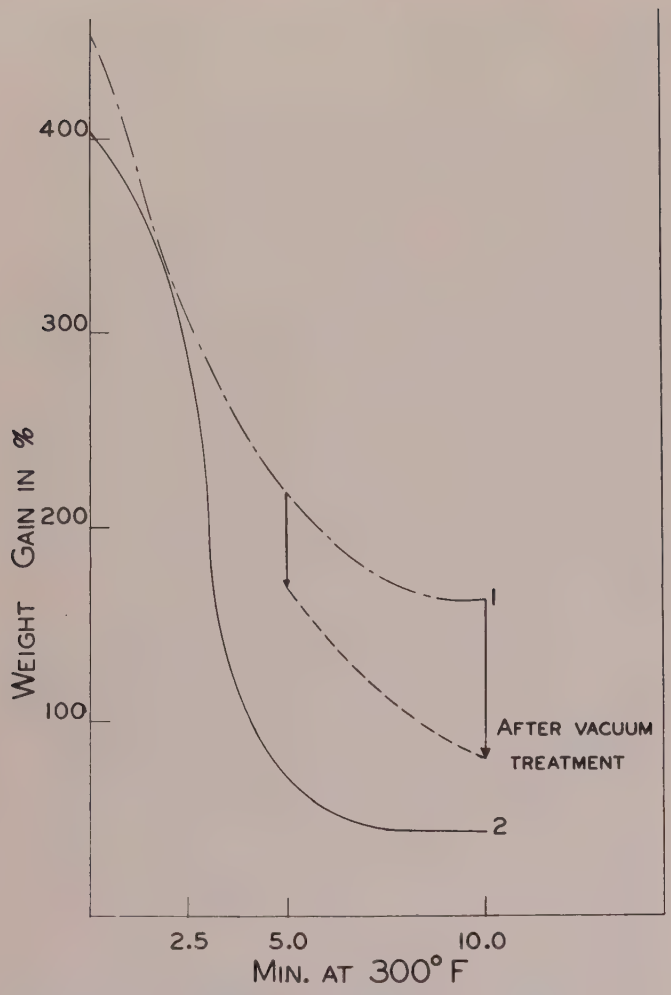


Fig. 4. Identification of moisture in phenolic resin-impregnated paper. Effect of vacuum treatment on weight-gain curve

tion. A weight gain test after vacuum treatment will tell the difference. The weight gain decreases significantly after moisture removal. Obviously, vacuum treatment would not have affected the weight gain if excessive weight gain was caused by lack of resin.

Insufficient Cure. A study of the weight gain curves reveals that resin-saturated paper will pick up more water before the cure cycle is complete. It follows, therefore, that resin-saturated paper subjected to a curing cycle will give a weight gain which is represented by a point located somewhere on the lower slope of the S-curve. Its exact location on the S-curve depends on two factors, (a) the degree of cure, and (b) the resin content of the paper.

In many instances, resin-saturated, cured paper is examined under conditions where both of these factors are unknown. Ordinarily, a low weight gain is expected in such paper. If it is high, the weight-gain test provides a simple qualitative tool to determine the cause for this condition: A second specimen of such paper is heated to 300°F. for 5 min., followed again by a weight-gain test. If the weight gain after the heating cycle remains essentially as high as the paper not subjected to heating, it may be concluded that the paper did not contain sufficient resin to convert it to water repellency. On the other hand, if the weight gain is substantially decreased as a result of the heating cycle, it is established that the resin-saturated paper had not yet been completely cured before.

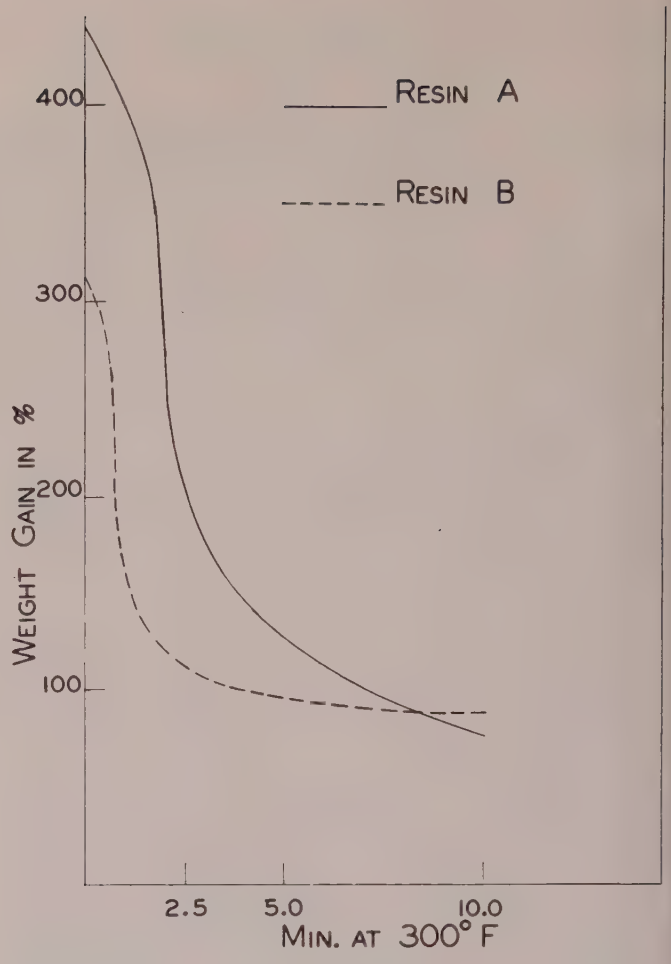


Fig. 5. Rate of cure of two phenolic resins shown by weight-gain patterns

Evaluations of Different Phenolic Resins

Two sheets of one lot of absorbent paper are saturated with two different phenolic resins, so that both sheets contain the same amount of dry resin solids. After drying to a volatile content of about 6%, weight gain data are obtained by the water immersion technique. The resulting weight-gain curves, giving the rate of cure at each cure time and temperature (Fig. 5) show that each resin has a characteristic curve of its own.

This result suggests the possibility of comparing the cure behavior of different phenolic resins at any desired temperature, by simply saturating an absorbent paper with equal amounts of resin solids, and subjecting the saturated sheets to the water immersion technique after identical curing cycles at identical temperatures. Further interesting possibilities are studies of variables in the preparation of a phenolic resin, e.g., condensation time and temperature, ratio of phenol to aldehyde, type and concentration of catalyst.

SUMMARY

The weight-gain test provides a new and simple technique for the determination of the quality of saturation and degree of cure in papers saturated for phenolic resins. The same method lends itself to the comparison of different phenolic resins and to the study of factors affecting resin condensation.

RECEIVED Sept. 25, 1959. Presented at the 14th Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry, held in Chicago, Ill., Sept. 20–23, 1959.

ASSOCIATION NEWS AND EVENTS

National Conferences

Eleventh Coating Conference, Edgewater Beach Hotel, Chicago, Ill., May 23–25, 1960.

Pulp Bleaching Conference, Edgewater Beach Hotel, Chicago, Ill., June 14–16, 1960.

Fourteenth Alkaline Pulping Conference, Multnomah Hotel, Portland, Ore., Aug. 22–24, 1960.

Forest Biology Conference, Seattle, Wash., Aug. 23–27, 1960.

Eleventh Testing Conference, Pantlind Hotel, Grand Rapids, Mich., Sept. 27–29, 1960.

Fifth Deinking Conference, Conway Hotel, Appleton, Wis., Oct. 5–7, 1960.

Tenth Corrugated Containers Conference, Royal York Hotel, Toronto, Canada, Oct. 10–13, 1960.

Fifteenth Plastics-Paper Conference, Hotel Syracuse, Syracuse, N. Y., Oct. 17–19, 1960.

Fifteenth Engineering Conference, Robert Meyer Hotel, Jacksonville, Fla., Oct. 24–28, 1960.

Local Section Meetings

Pacific: April 28, 29, 30, 1960, Bellingham, Wash., Annual Meeting; September, 1960, Salem, Ore., "Modernization."

Golden Gate District (Pacific Section): May 10, 1960, True Memorial Lecture, Hotel Claremont, Berkeley.

Lakes States: May, social meeting—date to be announced.

Delaware Valley: April 28, 1960, Engineers Club, Philadelphia, Pa., E. J. Albert Award Program; May 27, 1960, Beloit Eastern, Downingtown, Pa., tour and outing.

Kalamazoo Valley: April 21, 1960, Inman's Restaurant, Galesburg, "Stock Preparation"; May 12, 1960, Harris Hotel, Kalamazoo, Recognition Night, WMU Awards; June 21, 1960, Annual Golf Outing, Gull Lake Country Club.

New England: June 3–4, 1960, Chatham Bars Inn, Chatham, Mass., Spring Meeting.

Ohio: May 12, 1960, Hartwell Country Club, Cincinnati, Ohio, Ladies' night.

Ohio (Indiana District): April 19, 1960, Plant tour to be announced, "Coating," Brage Golding, Purdue University. May 17, 1960, Marott Hotel, Indianapolis, Ind., "Testing," Arthur Dreshfield, The Glidden Co.

Empire State: Whiteface Inn, Whiteface, N. Y., June 10–11, 1960.

Empire State (Metropolitan District): 465 Lexington Ave., New York, N. Y., May 13, 1960, Ladies' Night.

Empire State (Northern District): Woodruff Hotel, Watertown, N. Y., May 12, 1960, Annual Ladies' Night.

Empire State (Central District): University Club, 431 E. Fayette St., Syracuse, N. Y.

Empire State (Western District): Prospect House, Niagara Falls, N. Y.

Empire State (Eastern District): Queensbury Hotel, Glens Falls, N. Y., April 21, 1960, Symposium, "Wet End Machine Operation"; May 21, 1960, Annual Ladies' Night.

Maine-New Hampshire: June 17–18, 1960, Mountain View House, Whitefield, N. H., Annual Meeting.

Chicago: Chicago Bar Association, 29 S. LaSalle St., Chicago, Ill., May 3, 1960.

Southeastern: May 20–21, 1960, Savannah, Ga.

Gulf Coast: May 13, 1960, New Orleans, La.

1960 Conference—Study Group of European TAPPI Members: Lucerne, Switzerland, Sept. 12–16, 1960. All queries concerning hotels, etc., will be organized by R. Naville, Jenataschstrasse 4, Zürich 2, Switzerland, and the Lucerne Travel Bureau. All queries concerning the program should be sent to the secretary, I. F. Hendry, Butler's Court, Beaconsfield, Bucks, England.

Other Conferences

AIEE Annual Conference on Electrical Engineering in the Pulp and Paper Industry, University of Florida, Gainesville, Fla., April 21–22, 1960.

EuCePa Symposium on "Statistical Methods in the Pulp and Paper Industry," Helsinki University of Economics, Helsinki, Finland, May 16–18, 1960. Program details may be obtained from Nils Lindberg, Secretary-General EuCePa Symposium, Finnish Paper Engineers' Association, Unioninkatu 19, Helsinki, Finland.

Association Technique de L'Industrie Papetiere Annual Meeting, 13th Congress, May 29–June 3, 1960, at Aix-les-Bains (Savoie). Program details may be obtained from Paul Turel, Secretary-General, Association Technique de L'Industrie Papetiere, 154, Boulevard Haussmann, Paris, France.

Tenth Pacific Science Congress of the Pacific Science Association will be held at the University of Hawaii, Honolulu, from Aug. 21 to Sept. 6, 1961, sponsored by the National Academy of Sciences, Washington, D. C., and Bernice P. Bishop Museum, with the cooperation of the University of Hawaii. Scientific sessions will be held from August 21 to September 2, with a post-sessional field trip through September 6. Address all correspondence to: Secretary-General, 10th Pacific Science Congress Bishop Museum, Honolulu 17, Hawaii.

Third Cellulose Conference, Cellulose Research Institute, State University College of Forestry, at Syracuse University, Syracuse 10, N. Y., Oct. 27–28, 1960.

TAPPI Headquarters Staff Promotions

James R. Lientz, president of TAPPI, has announced a series of promotions involving members of the Association's headquarters staff. These new assignments were approved by the Executive Committee during the 45th Annual Meeting held in New York this past February.

Philip E. Nethercut, formerly Secretary-Treasurer, has been named Executive Secretary. In this capacity he will direct all operations of the headquarters staff. Mr. Nethercut joined the Association staff in 1957 as Technical Secretary and was appointed Secretary-Treasurer in 1959.

Ronald G. Macdonald, formerly Assistant to the President, has been named Treasurer and Editorial Director. In this new assignment Mr. Macdonald will direct and coordinate the publication activities and policies of the Association. Mr. Macdonald has served as an officer of the Association since 1928 and was appointed Assistant to the President last year.

A. John Winchester has been promoted from Technical Associate to Technical Secretary. In this capacity Mr. Winchester will coordinate the activities of the Association's technical divisions and the headquarters' technical staff. Mr. Winchester joined the Association staff as Technical Assistant in 1953 and was named Technical Associate in 1957.

James W. Field has been named Local Section Assistant,

in which assignment he will guide and assist the Association's local sections and districts. Prior to this new responsibility Mr. Field had served as Technical Assistant on the headquarters staff since 1957.

Research Studentships

The Wiggins Teape Group invites applications for two research studentships, each to a value of £500 p.a. sterling. These studentships, are designed for overseas graduates wishing to gain experience in the British paper industry, and to undertake fundamental studies in the properties and structure of paper. The studentships will be tenable at Butler's Court, Beaconsfield, where students will be able to make use of extensive modern equipment. There will be no objection to students using these studentships in conjunction with other grants. Applications should be sent to the manager, Wiggins Teape Group Research Organization, Butler's Court, Beaconsfield, Bucks, England.

1960 Annual Business Meeting

The 1960 Annual Business Meeting of the Association was held in the East Ballroom of the Commodore Hotel on Monday, Feb. 21, 1960. J. R. Lientz presided at this meeting, which was attended by well over the quorum required to transact Association business.

The meeting opened with a report on 1959 Association activities by P. E. Nethercut, secretary. This was followed by the president's annual address which will be published in the May issue of *Tappi*.

J. R. Lientz read the report of the Tellers Committee, announcing the election of J. R. Lientz as president, H. M. Annis as vice-president, and J. M. McEwen, A. H. Nadelman, K. D. Running, and H. A. Spencer as new Executive Committee members.

Two proposed amendments to the Association Constitution were submitted to the voting members present at the meeting. The first involved elimination of the class of overseas memberships and reassignment of overseas members to other classes. A. Abrams moved that this amendment be approved, and his motion was seconded by J. D. Lyall. It was passed unanimously by the voting members present.

The second amendment proposed that the title of secretary or secretary-treasurer be changed to executive secretary. R. P. Whitney moved that this amendment be approved. V. F. Waters seconded this motion, which was then passed unanimously.

The secretary was directed to send letter ballots on these two proposed amendments to all voting members of the Association. Approval by two thirds of the ballots returned is required for final approval.

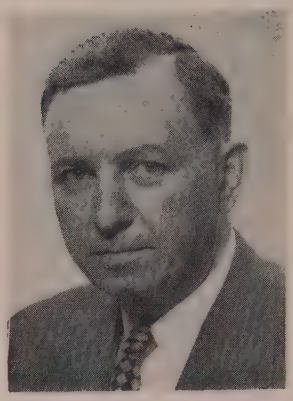
H. S. Spencer, chairman of the Joint Textbook Committee, reported briefly on the activities of this committee.

The meeting closed with the presentation of Certificates of Appreciation by J. R. Lientz to the following retiring chairmen: J. K. Kirkpatrick of the Mechanical Pulping Committee, J. T. Loomer of the Coating Committee, L. Price of the Paper Testing Committee, H. A. Smith of the Pulp Testing Committee, and R. C. Sturken of the Converting and Consuming Division.

Converting and Consuming Division

Joseph C. Pullman, American Cyanamid Co., New York, N. Y., has been appointed general chairman of the TAPPI Converting and Consuming Division, succeeding R. C. Sturken, Frank W. Egan Co., Somerville, N. J.; and K. W. Britt, Scott Paper Co., Chester, Pa., has succeeded Mr. Pullman as vice-chairman of the division.

Mr. Pullman is a past chairman of the Plastics Committee and was appointed vice-chairman of the Converting and Consuming Division a year ago. A native of Nova Scotia, he received his Ph.D. degree from McGill University, has been with American Cyanamid 17 years, and a member of TAPPI 24 years.



J. L. Pullman, American Cyanamid Co.

K. W. Britt, Scott Paper Co.

Mr. Britt is currently chairman of the Wet Strength and Interfiber Bonding Committee and has been a member of TAPPI since 1941.

The Converting and Consuming Division of TAPPI comprises three committees: Plastics, Plastics Laminates, and Wet Strength and Interfiber Bonding.

Forest Biology Symposium

A Forest Biology Symposium, sponsored by the TAPPI Forest Biology Committee, will be held Aug. 24–26, 1960, at the New Washington Hotel, Seattle, Wash.

The three-day conference will be designed to attract both woodlands men and mill people interested in wood quality, and special sessions will be devoted to discussion of problems shared by both mill men and foresters.

R. J. Seidl, Simpson Timber Co.

Registration for the conference is to be made in advance of the opening date. Preregistration forms will appear in the May issue of *Tappi*.

R. J. Seidl, Simpson Timber Co., Seattle, Wash., is general chairman of the symposium, and the technical program is being prepared by J. W. Duffield, W. B. Greely Forest Nursery, Nisqually, Wash. Local arrangements will be handled by R. Z. Callahan, U. S. Forest Service, Inland Empire Research Center, 5175 Howard St., Spokane, Wash.

A. J. Winchester, TAPPI, New York, will act as treasurer and publicity director for the conference.

Retiring Committee and Division Chairmen

Several retiring Technical Committee and Division Chairmen were honored with Certificates of Appreciation during the 45th Annual National Meeting of the Technical Association of the Pulp and Paper Industry.

The recipients of these certificates are:

Philip N. Joranson, research associate, The Institute of Paper Chemistry, Appleton, Wis., who served as chairman, Forest Biology Committee, from 1957–60.

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STOP SHOW-THROUGH

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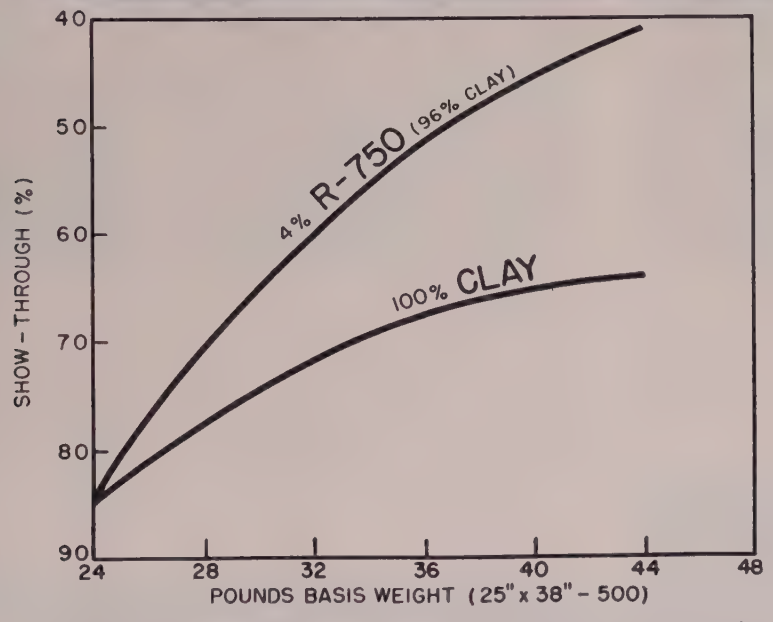
HIGH OPACITY HORSE HEAD® R-750

(RUTILE)

TITANIUM DIOXIDE



A lighter-weight sheet with greater resistance to show-through can be obtained by replacing only 4% clay with HORSE HEAD R-750 in the coating. The above results were obtained on a 24-lb. base stock coated one side only.

You need only moderate percentages of HORSE HEAD R-750 in your coating to obtain improved show-through resistance at lower basis weight. This means lower mailing costs for your customers.

Here's why:

HORSE HEAD R-750, having a rutile crystal structure, has a high refractive index . . . far higher than clay, even higher than anatase titanium dioxide.

HORSE HEAD R-750 is economical, too. In coated papers it provides more show-through resistance per dollar than anatase titanium dioxide.

HORSE HEAD R-750 is especially suited for use in coated papers of all types. It provides excellent color and brightness, good dispersion, low water demand, good flow properties in coating colors.

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Dr. Louis E. Wise accepting the TAPPI Medal

The Executive Committee of the Technical Association of the Pulp and Paper Industry, including newly elected Executive Committee members: Reading left to right, front, seated: J. P. Weidner, K. G. Chesley, J. R. Lientz, H. M. Annis, J. R. Curtis, R. G. Macdonald. Back: H. O. Ware, P. S. Cade, A. Abrams, F. P. Doane, Jr., J. M. McEwen, K. D. Running, J. H. Heuer, H. A. Spencer, W. C. Bloomquist, A. H. Nadelman, F. S. Klein, L. G. Rolland, J. J. Koenig

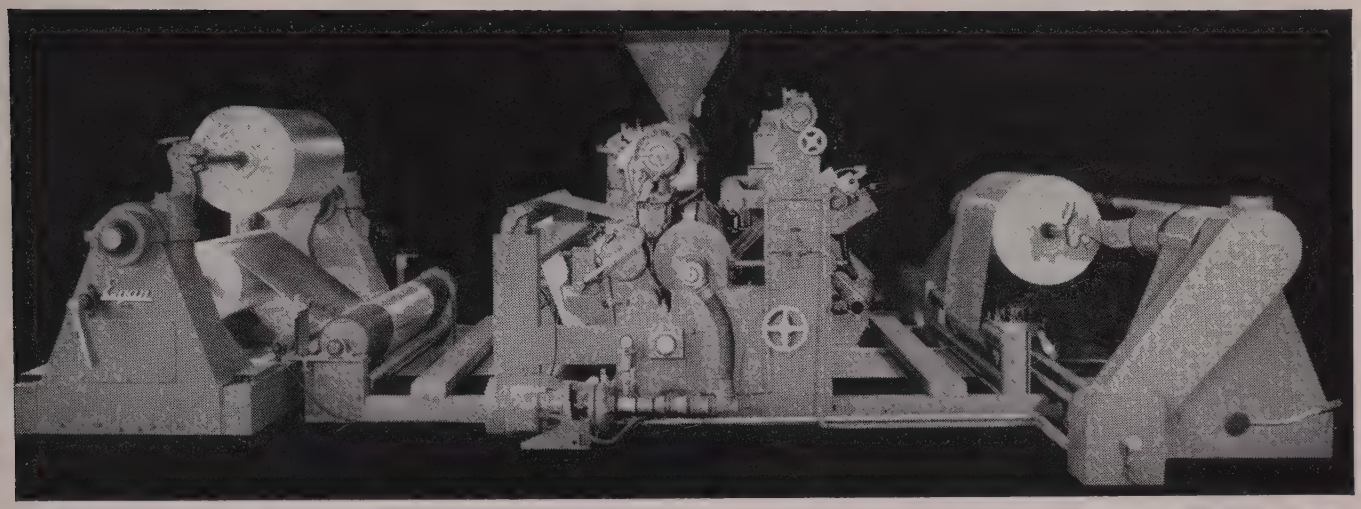
Newly elected members of the TAPPI Executive Committee: K. D. Running, J. M. McEwen, J. R. Lientz, H. A. Spencer, A. H. Nadelman, and H. M. Annis. Both Mr. Lientz and Mr. Annis were reelected for second-year terms as TAPPI President and Vice-President, respectively

Some of the foreign visitors and overseas TAPPI members attending the annual meeting, being greeted by Philip E. Nethercut, Executive Secretary of the Association. Left to right: P. E. Nethercut; G. Conciatore, Cartiere Ambrozio Binda, Crusillano, Italy; Luciano Pasero, Cartiere Ambrozio Binda; Lars-Henrik Forssblad, Marma-Langrors AB, Marmaverken, Sweden; H. W. Giertz, Technical University of Norway; Gunther Hunger, Institut fuer Cellulosechemie, Germany; and Piero Bersano, Cartiere Burgo, Italy

The 44th Annual TAPPI Luncheon

Pulp Purification Session at the 44th Annual Meeting

why an Egan extrusion coater?



Above unit installed at Protective Coatings Corporation, Clifton, New Jersey

One minute's reading time tells you why!

Egan is the world's leading manufacturer of extrusion coating equipment. Eighty-five percent of all companies operating extrusion coater-laminators rely on Egan field-tested equipment.

The extruder itself is a proven, dependable, high-capacity, low maintenance unit. Barrel thickness is calculated for optimum heat transfer. Inexpensive high watt-density ceramic resistance heater bands provide fast heat-up, and *improve* your plant's power factor (ceramic heater bands are economical to buy *and* operate).

The center fed, single piece die minimizes dead storage areas and leakage. Rectangular construction lends itself to more even heating without warpage. Standard or extended die jaw designs are available.

Critical parts of the extruder and die are precision manufactured to close tolerances, permitting accurate gauge control and production of thinner films.

A specially designed double-shell internal spiral chill roll, furnished with mirror or matte finish, assures maximum heat transfer rates for cooling the laminate uniformly (less than 2° F differential across roll). It further permits use of smaller diameter cooling rolls which reduces trim losses, the largest single factor in production waste.

Various laminator designs can be furnished, depending upon the substrate to be handled. Open construction of the laminator permits maximum access and visibility by the operator.

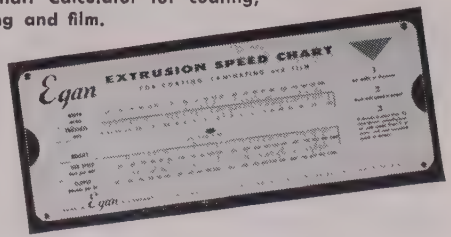
Packaged water circulating and trim disposal systems are also provided.

In addition, patented horizontal and vertical adjustments of the laminating nip, which are essential for obtaining maximum adhesion, are included.

A variety of unwinds and winders can be furnished, depending upon individual requirements (from hand-splice operations to automatic flying splice and flying transfer equipment).

In short, Egan gives you the complete machine package, manufacturing both the extruder and the web handling equipment.

FREE Write for your free Egan Extrusion Speed Chart Calculator for coating, laminating and film.



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H. F. Lewis and L. E. Wise, The Institute of Paper Chemistry; and J. R. Lientz, Union Bag-Camp Paper Corp.

H. M. Annis, Oxford Paper Co.; H. E. Whitaker, The Mead Corp.; and W. T. Bennett, Canadian International Paper Co.

A. Abrams, A. D. Little; J. M. McEwen, Weyerhaeuser Co.; J. R. Curtis, Scott Paper Co.; R. G. Macdonald, TAPPI; and Miss Anne E. Toomey, Salesmen's Association of the Paper Industry

R. G. Macdonald, TAPPI; Miss Anne E. Toomey, Salesmen's Association of the Paper Industry; F. L. Mitchell, Canadian Pulp and Paper Association; and A. C. McCorry, St. Regis Paper Co.

H. E. Weston, Paper Industry Management Association; Douglas Jones, Canadian Pulp and Paper Association; and P. E. Nethercut, TAPPI

K. G. Chesley, The Crossett Co.; C. D. Running, Halifax Paper Co.; H. A. Spencer, Knowlton Bros.; and J. P. Weidner, Container Corp. of America

Tests Prove* V-10

"Safe for use in any Food Board Mill"

Rigorous tests to determine biocidal migration from the board to typical food types have proven Vineland's V-10 safe for any normal use in all food board mills. Using procedures recommended by the Federal Food and Drug Administration, representative types of paper and paperboard food packaging materials, manufactured in mills using V-10 as the biocide, were tested by a recognized Eastern laboratory to determine V-10's status under usage, within the meaning of the 1958 Food Additives Amendment.

The results indicated that no migration occurred from paper or paperboard manufactured in mills using Vineland V-10! Since no migration is expected from paper packaging materials treated with V-10, its use is not subject to the Food Additives Amendment.

Use V-10 to rid your mill of all slime problems. Vineland's technical staff is always ready to assist in helping you to establish proper slime control. Bacterial population and prevalent micro-organisms will be determined at your request without cost or obligation. Write or telephone (OXford 1-3535) for free booklet "Control of Slime in the Paper Mill."

* *Test results available on request.*

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Lafayette Price, U. S. Government Printing Office; R. C. Sturken, F. W. Egan Co.; J. R. Lientz, Union Bag-Camp Paper Corp.; J. K. Kirkpatrick, Bowaters Southern Paper Corp.; H. A. Smith, The Mead Corp.; and J. T. Loomer, Continental Can Co.

John K. Kirkpatrick, assistant groundwood mill superintendent, Bowaters Southern Paper Corp., Calhoun, Tenn.; chairman—Mechanical Pulping Committee, 1958–59.

Joseph T. Loomer, manager of sales, Continental Can Co., Inc., Robert Gair Products Group, New York, N. Y.; chairman—Coating Committee, 1959–60.

Malcolm B. Pineo, technical director, Brunswick Pulp & Paper Co., Brunswick, Ga.; chairman—Pulp Manufacture Division, 1957–60.

LaFayette Price, paper chemist, U. S. Government Printing Office, Washington, D. C.; chairman—Paper Testing Committee, 1955–60.

Herbert A. Smith, technical director, Tech. Service Dept., Mead Corp., Chillicothe, Ohio; chairman—Pulp Testing Committee, 1957–59.

Robert C. Sturken, vice-president and treasurer, Frank W. Egan Co., Somerville, N. J.; chairman—Converting and Consuming Division, 1958–60.

They will be succeeded by newly appointed chairmen, whose names will be announced later.

Eleventh Coating Conference

The Eleventh Annual TAPPI Coating Conference will be held at the Edgewater Beach Hotel, Chicago, Ill., May 23–25, 1960. The general chairman of the conference is R. W. Hagemeyer, Wyandotte Chemicals Corp., Wyandotte, Mich. Technical program chairman is R. W. Martinek, Kimberly-Clark Corp., Neenah, Wis., W. E. Welliver, Minerals & Chemical Corp., Menlo Park, N. J., is publicity chairman, and local arrangements chairman is C. W. Cairns, The Dow Chemical Co., Midland, Mich.

Reservations for sleeping accommodations during the conference should be addressed to the Edgewater Beach Hotel, Chicago, Ill.

The complete program of the conference is given below.

SUNDAY, MAY 22, 1960

4:00–6:30 p.m. Registration (Passagio)
8:00–10:00 p.m. Registration (Passagio)

MONDAY, MAY 23, 1960

8:00 a.m. Coating Committee Meeting (Ballroom)

J. E. Wilber, St. Regis Paper Co., Deferiet, N. Y., *Chairman*

8:30 a.m. Registration (Passagio)

10:30 a.m. First Session (Ballroom)

L. A. Gilbertson, Marathon Division, American Can Co., Neenah, Wis., *Chairman*

Opening remarks, R. W. Hagemeyer, Wyandotte Chemical Corp., Wyandotte, Mich.

1. "New Surface Sizing Technique with Polyvinyl Alcohol," by B. A. Beardwood and E. P. Czerwin, E. I. du Pont de Nemours & Co., Wilmington, Del.
2. "Coating Polymers for Paper Products," by W. L. Boyer, Firestone Plastics Co., Pottstown, Pa.

1:30 p.m. Second Session (Ballroom)

A. W. Neubauer, Crown Zellerbach Corp., Camas, Wash., *Chairman*

3. "European Approach to Printability Research," by M. C. Rogers, Chicago Paper Testing Laboratory, Chicago, Ill.
4. "New Developments in Offset Printing," by M. Bruno, Lithographic Technical Foundation, Chicago, Ill.
5. "The Effect of Pigment Binders on Paper Gloss, Printed Gloss, and oil absorption," by R. E. Weber, Kimberly-Clark Corp., Neenah, Wis.
6. "The Effect of Mixing Intensity on the Dispersion of Coating Pigments in Water," by N. Millman and J. B. Whitley, J. M. Huber Corp., Huber, Ga.

TUESDAY, MAY 24, 1960

8:30 a.m. Registration (Passagio)
9:00 a.m. Third Session (Ballroom)

Panel Symposium—"Coating for Printing."

H. H. Lavery, International Paper Co., Corinth, N. Y., *Chairman*

Walter W. Roehr, Kimberly-Clark Corp., Neenah, Wis., *Moderator*

Graphic Art Panelists:

"Coated Board Printing," by L. R. Ayers, Continental Can Corp., Inc., Robert Gair Paper Product Group, Elkhardt, Ind.

"Offset Printing," Charles H. Borchers, Lithographic Technical Foundation, Inc., Chicago, Ill.

"Rotogravure Printing," Frederick W. Goetz, Publication Corp., New York, N. Y.

"Rotogravure Printing," Frederick W. Goetz, Publication Corp., New York, N. Y.

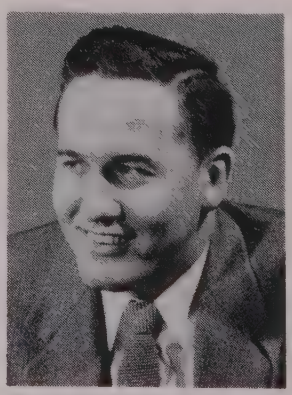
"Letterpress Printing," Marvin C. Rogers, Chicago Paper Testing Laboratory, Chicago, Ill.

Coating Panelists:

"Letterpress and Rotogravure Printing," Philip C. Evanoff, The Mead Corp., Chillicothe, Ohio.

"Offset Printing," Alger P. Reynolds, S. D. Warren Co., Cumberland Mills, Me.

"Coated Board Printing," Willard I. Stinger, Marathon Div., American Can Co., Neenah, Wis.



R. W. Hagemeyer, Wyandotte Chemicals Corp.

C. W. Cairns, The Dow Chemical Co.

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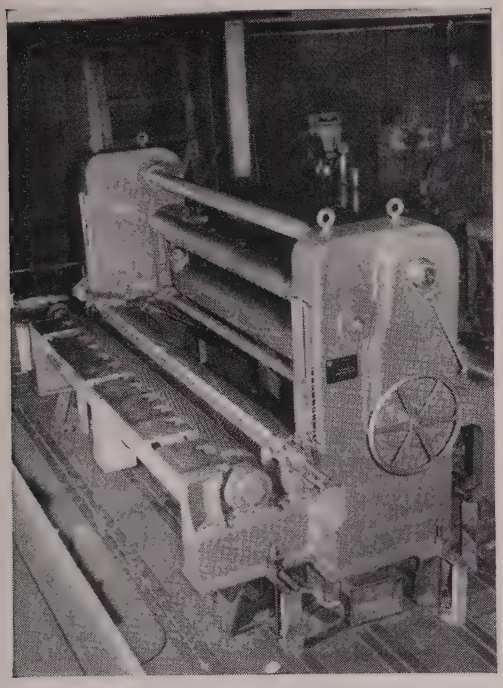
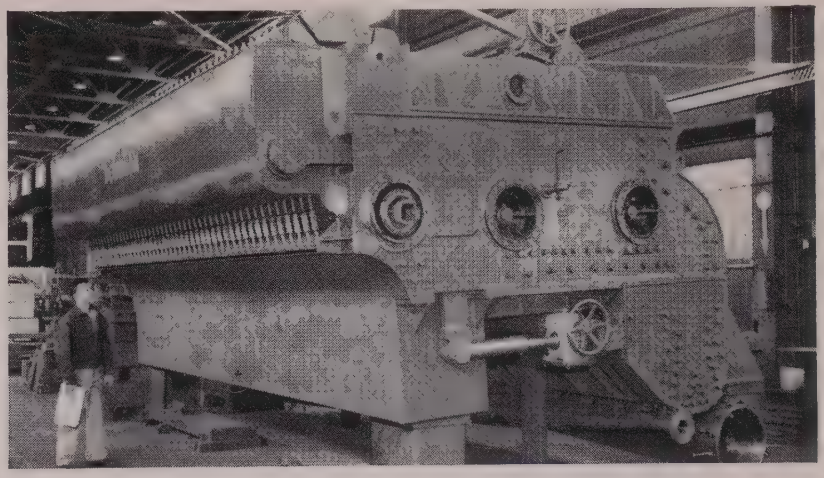
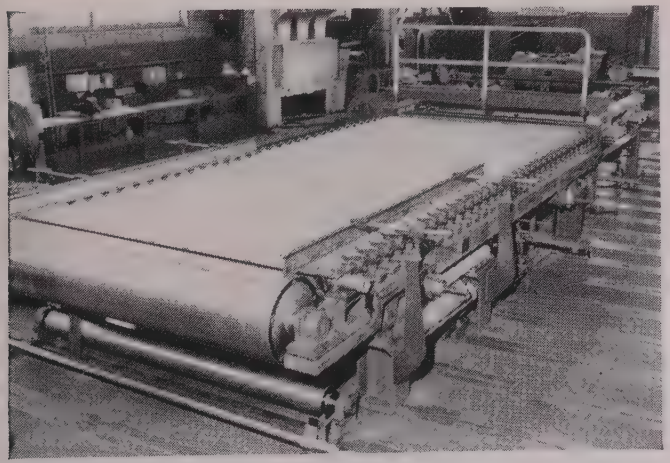
Dominion Engineering designs and builds complete paper, pulp, board and specialty machines of all types, and components particularly suited for modernization and modification of existing machines, including Pressure Head Boxes—Fourdriniers—Couch and Press Sections—Suction Rolls—Dryers—Calenders—Reels—Winders and Rewinders—Mechanical Drives—Pulp Grinders—Electric Steam Generators.



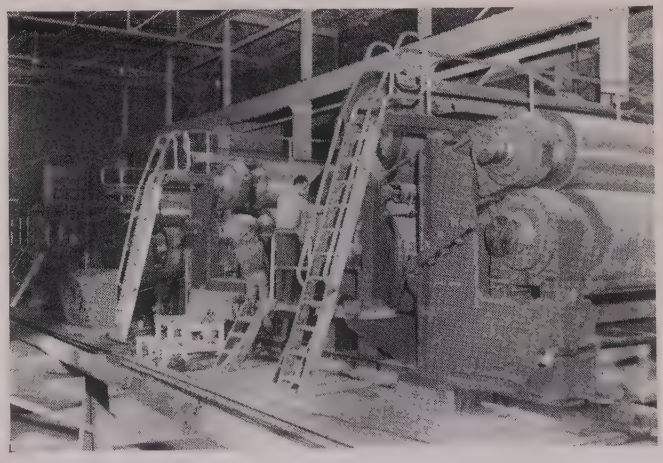
DOMINION WINDERS AND REWINDERS cover the full range from small low speed rewinders to the highest speed news machine winders. Designed to ensure maximum stability under all operating conditions, they incorporate automatic riding roll load control, readily adjustable slitters of either the shear cut or score cut type, a variety of paper unloading arrangements and special winder drum fluting to reduce noise.



DOMINION PRESSURE HEADBOXES incorporate such advanced design features as: fully adjustable slice; parabolic cross-flow distributors and hydraulic rectifier roll drives. Dominion Pressure Headboxes are installed on many fine paper and newsprint machines to increase production and improve product quality.



DOMINION FOURDRINIERS are designed and built to mill requirements: fixed or removable, shaking, which incorporate the patented Torsion Bar Suspension, or non-shaking, etc. Dominion Fourdriniers reduce wire changing time. Most important, complete designing and manufacturing control by Dominion Engineering means total responsibility and service to users of Dominion equipment.



DOMINION SUCTION ROLLS benefit from many years of experience and development and incorporate such features as open ended design for accessibility combined with anti-friction bearings, floating suction box tops and drilling patterns designed to reduce noise level and shadow marking. The shells can be provided in all sizes in bronze or forged stainless steel, the latter permitting the high line pressures available from Dominion oil-hydraulic loaded press sections.

TUESDAY, MAY 24, 1960

1:30 p.m. Plant trips

A. Corn Products Co., Argo plant (Cook County), Chicago, Ill.
B. Rand McNally Co., Skokie, Ill.
C. Trips are being arranged to letterpress and rotogravure printing plants.

WEDNESDAY, MAY 25, 1960

8:30 a.m. Registration (Passagio)
9:00 a.m. Fourth Session (Ballroom)

C. A. Richardson, Blandin Paper Co., Grand Rapids, Minn. *Chairman*

7. "Electrostatic Coating Process for Making Flat Gummed Paper," by F. W. Holt and C. L. Lorenz, Brown Bridge Mills, Troy, Ohio, and R. B. Reif, Battelle Memorial Institute, Troy, Ohio.
8. "Design and Operation of Pilot Plant Coaters," by E. D. Jones, Crossett Paper Mills, Crossett, Ark., and N. H. Laughrey, Black-Clawson Co., Dilts Div., Fulton, N. Y.
9. "A Method to Determine the Degree of Web Rub Resistance," by F. Ray Adams, Jr., International Paper Co., New York, N. Y.
10. "Operating Variables of a Blade Coater," by W. J. Follette and R. W. Fowells, Crown Zellerbach Corp., Camas, Wash.
11. "The Champflex Coater," by C. G. Whelpton, Champion Paper and Fibre Co., Hamilton, Ohio.

WEDNESDAY, MAY 25, 1960

12:30 p.m. Annual luncheon (Polynesian Village)

R. W. Hagemeyer, Wyandotte Chemicals Corp., Wyandotte, Mich., *Chairman*

Guest Speaker: Bert Cremers, Vice-President, Wyandotte Chemicals Corp.

WEDNESDAY, MAY 25, 1960

2:30 p.m. Fifth Session (Ballroom)

J. T. Goodwin, Jr., Corn Ind. Res. Foundation, Inc., Washington 6, D. C., *Chairman*

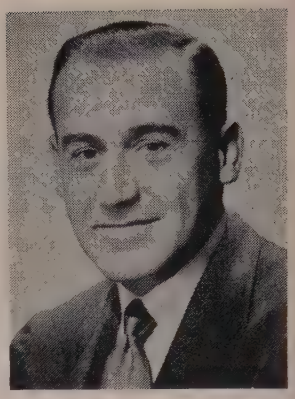
12. "A New Precision Technique for Measurement of Coating Thickness," by H. H. Murray, Georgia Kaolin Co., Elizabeth, N. J., and W. D. Johns, Washington University, St. Louis, Mo.
13. "A Laboratory Instrument for Measuring the Piling Propensity of Papers Used in Offset Lithography," by Frank F. Oehme and Don C. Nepper, Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis.
14. "Pressure Cooking for Coating Color Preparation," by W. C. Black and V. L. Winfrey, Penick and Ford, Ltd., Inc., Cedar Rapids, Iowa.

Banquet Speaker

The featured speaker at the Eleventh TAPPI Coating Conference will be Bert Cremers, vice-president and director, Wyandotte Chemicals Corp.; general manager, Michigan Alkali Div.; president, Wyandotte Chemicals International, Inc.

Mr. Cremers has extensive experience in the sales, marketing, and management fields. His business career began in 1911 as a retail sales clerk. At various times in his life he was an apprentice printer; salesman for a real estate company, wholesale paper company, and a soap company. In 1927 he entered the chemical sales field.

One of Mr. Cremers' main interests is in the training and developing of executive manpower. He has written numerous articles and conducted seminars on this subject. Many men trained under him hold important positions in the general management field.



Bert Cremers, Wyandotte Chemicals Corp.

Mr. Cremers has numerous business affiliations including being a member of the Advisory Committee of the Chlorine Institute; a member of the Advisory Council of Detroit Sales Executives Club; a past trustee of the Glass Container Manufacturers Institute; a member of the Chemists' Club; a member of the Manufacturing Chemists' Association, and the Economic Club of Detroit.

In view of Mr. Cremers' prominent position in the marketing field, his talk which is keyed to this general area should be enlightening to all those in attendance at the luncheon on Wednesday, May 25, 1960.

Pulp Bleaching Conference

The Pulp Bleaching Conference, sponsored by the Pulp Purification Committee of the Technical Association of the Pulp and Paper Industry, will be held June 14–16, 1960, at the Edgewater Beach Hotel.

R. J. Auchter, Kimberly-Clark Corp., Neenah, Wis., technical program chairman, has announced the program.

The Pulp Bleaching Conference offers six technical sessions, 16 technical papers, a technical panel and discussion sessions (as detailed below).

The conference includes papers devoted to theoretical aspects as well as those having immediate practical significance. The authors and moderators will be recognized as outstanding international experts in the field of pulp bleaching.

Assisting Mr. Auchter in developing the technical program were J. F. Whalen, Combined Locks Paper Co., Combined Locks, Wis., and J. D. Wethern, Riegel Paper Corp., Acme, N. C.

Ferdinand Kraft, Marathon Division of American Can Co., Menasha, Wis., is general chairman, and Herbert O. Teeple, of TAPPI, New York, is in charge of the general arrangements for this conference.

TECHNICAL PROGRAM

MONDAY, JUNE 13, 1960

12:00 Noon–8:00 p.m. ***Registration (Foyer—Michigan Room)***
2:00 p.m. ***Pulp Purification Committee (Balmoral Room)***
6:00 p.m.–7:30 p.m. ***Overseas Visitors' Reception (West Lounge)***

TUESDAY, JUNE 14, 1960

7:30 a.m. ***Authors' Breakfast (Alcove—Charterhouse Room)***
8:00 a.m.–4:00 p.m. ***Registration (Foyer—Michigan Room)***
9:00 a.m. ***Session I, F. Kraft, Moderator***

Opening Remarks—F. Kraft, Marathon Div., American Can Co., Menasha, Wis., General Conference Chairman and Chairman, Pulp Purification Committee.

1. "Theory of Optical Properties of Pulp," by J. A. Van den Akker, The Institute of Paper Chemistry, Appleton, Wis.

What's the best way to bleach cold caustic pulp...

TOWER or REFINER?

Let Du Pont—the producer of both hydrogen peroxide and sodium peroxide—help you make this key decision

You may save thousands of dollars in capital investment and chemical cost if you make the right choice between bleaching in a refiner or in a tower.

Du Pont has a thorough working knowledge of both systems and, as the producer of both sodium peroxide and hydrogen peroxide, can tell you which peroxide or combination of peroxides is best for you.

Du Pont technical men will work with you and the equipment manufacturer of your choice to obtain the best peroxide bleaching process for your cold caustic pulp. They may recommend refiner bleaching requiring a small investment for peroxide solution make-up equipment with possible brightness increases of up to 20 points . . . or if your operation calls for it, they may recommend tower bleaching. When combined with Du Pont's acidification process and a peroxide treatment, tower bleaching can increase brightness up to 35 points.

Add Du Pont's experience to your own, and you're sure to make the right choice. Call your Du Pont representative; he will be glad to discuss any bleaching problem you may have.

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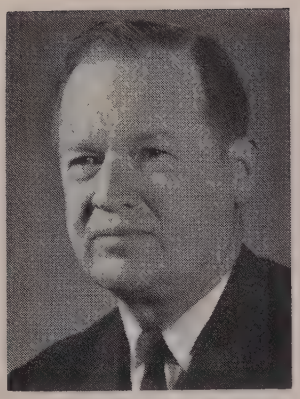

R. J. Auchter, Kimberly-Clark Corp.

Ferdinand Kraft, Marathon Div., American Can Co.

2. "Optical Properties of Highly Bleached Pulps," by J. H. E. Herbst, Industrial Cellulose Research Ltd., Hawkesbury, Ont.
3. "Brightness Reversion," by I. H. Spinner, University of Toronto, Toronto, Ont.
   Discussion of these three papers.

12:30 p.m. Luncheon (Polynesian Village*)

2:00 p.m. Session II (Michigan Room)

R. J. Stevens, Canadian International Paper Co., Montreal, Que., *Moderator*

4. "Chlorination of Wood Pulp," by C. Dence, State University College of Forestry, Syracuse University, Syracuse, N. Y.
5. "The Alkaline Extraction of Wood Pulp," by M. Wayman, Sandwell International Ltd., Vancouver, B. C.
6. "Hypochlorite Bleaching," by J. M. McEwen, Weyerhaeuser Timber Co., Everett, Wash.
   Discussion of these three papers.
   Dinner—where you will.

WEDNESDAY, JUNE 15, 1960

7:30 a.m. ***Authors' Breakfast (Alcove—Charterhouse Room)***

8:00 a.m.–4:00 p.m. ***Registration (Foyer—Michigan Room***

* Dining Room, Edgewater Beach Hotel.

9:00 a.m. Session III (Michigan Room)

F. Casciani, P. H. Glatfelter Co., Spring Grove, Pa., *Moderator*

7. "Peroxide Bleaching of Kraft Pulps," by N. Hartler, The Central Laboratory of the Swedish Cellulose Industry, Swedish Forest Products Research Laboratory, Stockholm, Sweden.
8. "Status and New Developments in Peroxide Bleaching of Pulps," by F. L. Fennell, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.
9. "Laboratory Studies on Bleaching New Zealand Pinus Radiata Kraft Pulp," by G. A. Nicholls, New Zealand Forest Products, Ltd., Penrose, Auckland, New Zealand.
   Discussion of these three papers.

12:30 p.m. Luncheon (Polynesian Village)

2:00 p.m. Session IV (Michigan Room)

F. P. Doane, Bergstrom Paper Co., Neenah, Wis., *Moderator*

10. "Studies on the Mechanism of Chlorine Dioxide Bleaching," by K. V. Sarkanen, State University College of Forestry, Syracuse University, Syracuse, N. Y.
11. "Chlorine Dioxide Bleaching," by W. H. Rapson, University of Toronto, Toronto, Ont.
12. "Some Aspects on the Bleaching of High Yield Chemical Pulps," by H. W. Giertz, The Technical University of Norway, Trondheim, Norway.
    Discussion of these three papers.
    Dinner—where you will.

THURSDAY, JUNE 16, 1960

7:30 a.m. ***Author's Breakfast (Alcove—Charterhouse Room)***

8:00 a.m.–12:00 Noon ***Registration (Foyer—Michigan Room)***

9:00 a.m. ***Session V (Michigan Room)***

H. V. Bialkowsky, Weyerhaeuser Timber Co., Longview, Wash., *Moderator*

13. "Materials of Construction for Modern Bleaching Systems," by R. L. Allen, Jr., Eastern Engineering Co., Atlanta, Ga.
14. "The Use of Reducing Agents," by J. L. Keays, MacMillen, Bloedel and Powell River Ltd., Powell River, B. C.

TAPPI PULP BLEACHING CONFERENCE

June 14–16, 1960 ***Edgewater Beach Hotel, Chicago, Ill.***

If you are planning to attend the Pulp Bleaching Conference, it will be to your advantage to indicate your intention (if you haven't already done so) by completing the form below and returning it promptly to H. O. Teeple, TAPPI 360 Lexington Ave., New York 17, N. Y.

This information will help in ascertaining the probable attendance and thus assure a better preparation for accomodations and facilities.

Name _____ Position _____

Company _____

Address (in full) _____

_____

Will your wife be attending with you, yes ——, no ——?

If you wish to make your hotel reservation, please send your request to

TAPPI Pulp Bleaching Conference
Edgewater Beach Hotel
Chicago 40, Ill.

and state time and date of both arrival and departure. Confirmation of your reservation will be made directly to you by the hotel.

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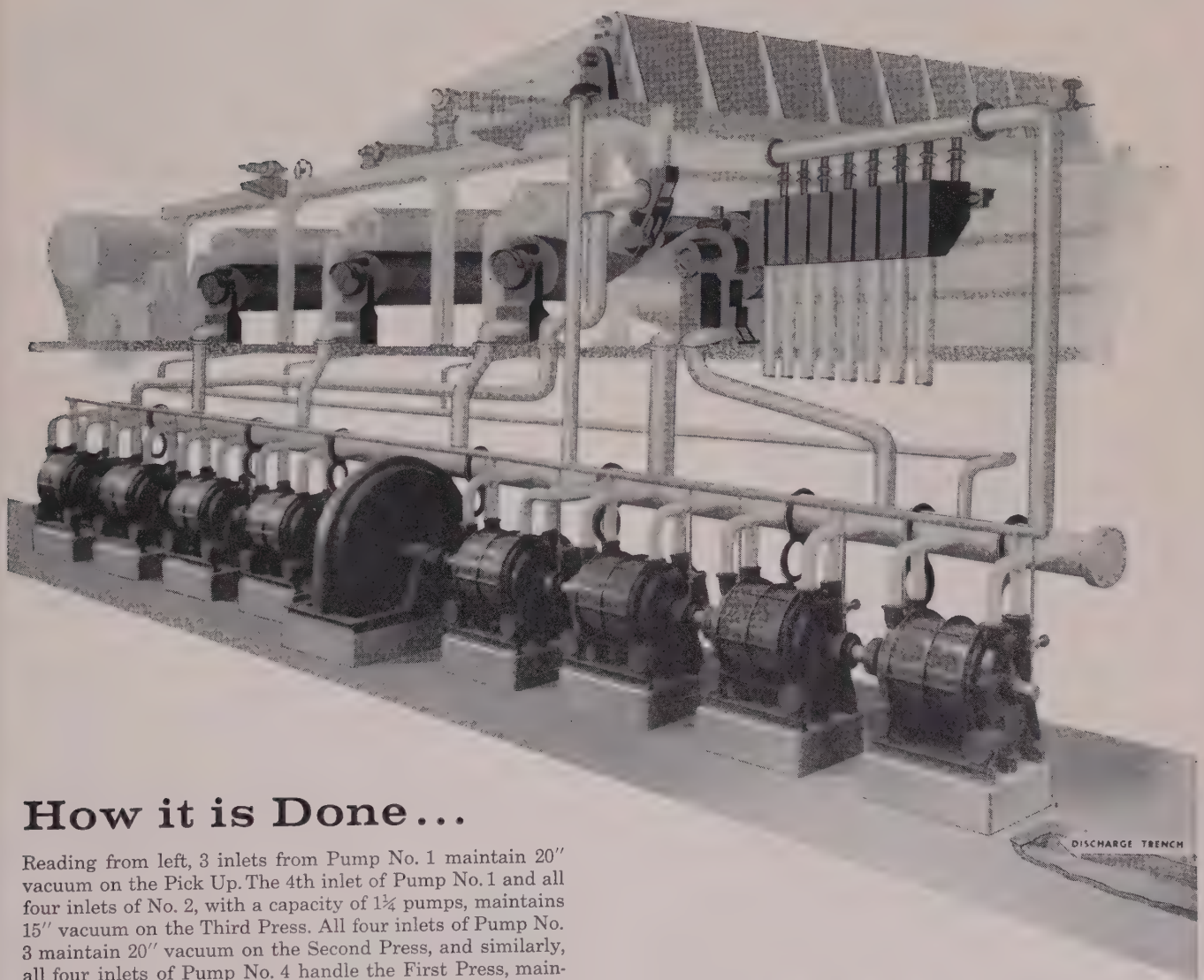
Nash Vacuum Pumps of one size, driven if desired, by a single motor, will handle all of the varied vacuum and capacity requirements of an entire Paper Machine.

Designed by Nash especially for Paper Mill service, the new 5308 vacuum pump has four separate suction inlets, each of which functions independently of the others. This offers the machine operator great flexibility, since these may be used in any desired combination to produce the variety of capacities and vacuums required by the various functions of a paper machine. These may be varied at will. Great simplicity of operation, and economy of maintenance results. The enclosed discharge trench makes possible a comparatively silent installation and permits easy and economical water recovery.



How it is Done...

Reading from left, 3 inlets from Pump No. 1 maintain 20″ vacuum on the Pick Up. The 4th inlet of Pump No. 1 and all four inlets of No. 2, with a capacity of 1¼ pumps, maintains 15″ vacuum on the Third Press. All four inlets of Pump No. 3 maintain 20″ vacuum on the Second Press, and similarly, all four inlets of Pump No. 4 handle the First Press, maintaining 20″ vacuum. The Wringer Roll takes the full capacity of Pump No. 5, requiring 10″ vacuum. The High Vacuum Couch Box takes a pump and a half, 4 inlets of Pump No. 6, and two inlets of Pump No. 7, maintaining 20″ vacuum. The remaining two inlets of Pump No. 7 maintain 10″ vacuum on the Low Vacuum Couch Box. Only one inlet of Pump No. 8 is required to handle the Felt Conditioners at 10″ and the remaining three inlets of Pump No. 8 handily maintain 10″ vacuum on the Wire Boxes.

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15. "Effect of Bleaching on Papermaking Properties," by M. H. Voelker, The Institute of Paper Chemistry, Appleton, Wis.
16. "The Effects of Additives and Treatments on Bleached Pulps," by R. H. Boehm, Kimberly-Clark Corp., Neenah, Wis.

Discussion of these four papers.

12:30 p.m. Luncheon (Polynesian Village)
2:00 p.m. Session VI (Michigan Room)

R. P. WHITNEY, The Institute of Paper Chemistry, Appleton, Wis., *Moderator*

Panel Discussion (theme to be announced).
Panel Members: H. W. Giertz, N. Hartler, W. H. Rapson, R. J. Stevens, J. A. Van den Akker.
Closing Remarks—F. Kraft.

5:00 p.m. Adjournment

Ninth Statistics Course

The Ninth Pulp and Paper Statistics Course will be held Aug. 8–19, 1960, at Brevard College, Brevard, N. C., and will be jointly sponsored by the Institute of Statistics of North Carolina State College, the Technical Section of the Candian Pulp and Paper Association, and TAPPI.

Two courses of instruction, one basic and one advanced, will be held concurrently during the 2-week period.

The Elementary Course is intended for those people who wish to acquire some knowledge of, and facility with, the simpler but exceedingly valuable statistical techniques and who have had little or no previous formal training in statistical methods. The training received from this course should prove profitable to organizations now making little or no use of statistical methods but wishing to know more about how they work and how to use them. It will also be profitable to organizations with statistical programs already operating who wish to strengthen their position by having additional men with statistical training available within their organization.

The Advanced Seminar is intended for people who have experience and definite facility in the use of statistical techniques and who wish to gain training and practice in special problems that arise in application. The course will consist of laboratory sessions devoted to the consideration of specific problems in the industry, and the practical analysis of these problems.

Further information and application forms for the course may be obtained from the Institute of Statistics, North Carolina State College, Raleigh, N. C.

Eleventh Testing Conference

W. H. Aiken, Personal Products Corp., Milltown, N. J., general chairman of the Eleventh TAPPI Testing Conference, has announced that a high light of the conference will be a symposium on "Relative Humidity and Paper Test Methods."

The conference will take place Sept. 27–29, 1960, at the Pantlind Hotel, Grand Rapids, Mich.

T. W. Lashof, National Bureau of Standards, Washington, D. C., is chairman of the relative humidity symposium, and W. R. Willets, Titanium Pigment Corp., New York, N. Y., is general program chairman for the conference.

The physical properties of paper change appreciably for quite small changes in relative humidity. Present standards for the testing of paper call for a conditioning and testing room to be controlled to 50 ± 2% relative humidity and 23 ± 2°C. Some feel that even these narrow limits will result in significant variations in the measured properties of the paper.

Because of the serious difficulties encountered in controlling and measuring the relative humidity of a test room to such narrow limits as are now specified for paper, and the possibility that even narrower limits are required, ASTM Committee D-6 on Paper and Paper Products and the TAPPI Testing Division are jointly sponsoring the symposium on this subject.

W. H. Aiken, Personal Products Corp.

T. W. Lashof, National Bureau of Standards

The tentative program for the symposium is given below.

W. E. Bennett, Research Physicist, and Miss D. M. Crook, British Paper & Board Industry Research Association: "Effect of Relative Humidity on Some Physical Properties of Paper."

Miss G. A. Bernier, group leader, Statistical Services, and W. E. Carlson, manager of Central Research, St. Regis Paper Co. "The Effect of Relative Humidity on the Stress-Strain Properties of Kraft Multiwall Paper."

W. Brecht, professor dr.-ing., Institut für Papierfabrikation, Technische Hochschule Darmstadt: "Reasons for 65% R.H. and 20°C., and Other Topics."

Willmer A. Wink, chief, Paper Evaluation Section, The Institute of Paper Chemistry: "Effect of Relative Humidity on the Evaluation of Paper Properties."

A. C. Poulter, B.Sc., Group Research Department, Research and Development Division, Albert E. Reed & Co., Ltd.: "Some Developments in the Measurement of Relative Humidity."

Arnold Wexler, research engineer in charge of Humidity Standards Laboratory, National Bureau of Standards: "Standards in the Measurement of Relative Humidity."

J. A. Cairns, The Printing, Packaging & Allied Trades Research Association: "The Design and Control of Test Rooms and Small Ovens."

L. L. Clapp, process and production development engineer, Technical Div., St. Regis Paper Co.: "A Conditioning Room in Which a Great Deal of In and Out Traffic Does Not Upset Conditions; a Rapid Conditioner."

Frank M. Gavan, chairman ASTM Committee E-1, Sub. 14, on Conditioning and Weathering, and Manager, Physical Test Department, Armstrong Cork Co. "The Constant Temperature Room as a Testing Facility: Its Design and Construction from a User's Viewpoint."

Ample time is being provided for discussion of the papers and general discussion. Also manufacturers of relative humidity measuring and controlling equipment as well as those who have installed such equipment in paper test rooms will have representatives or exhibitors at the symposium.

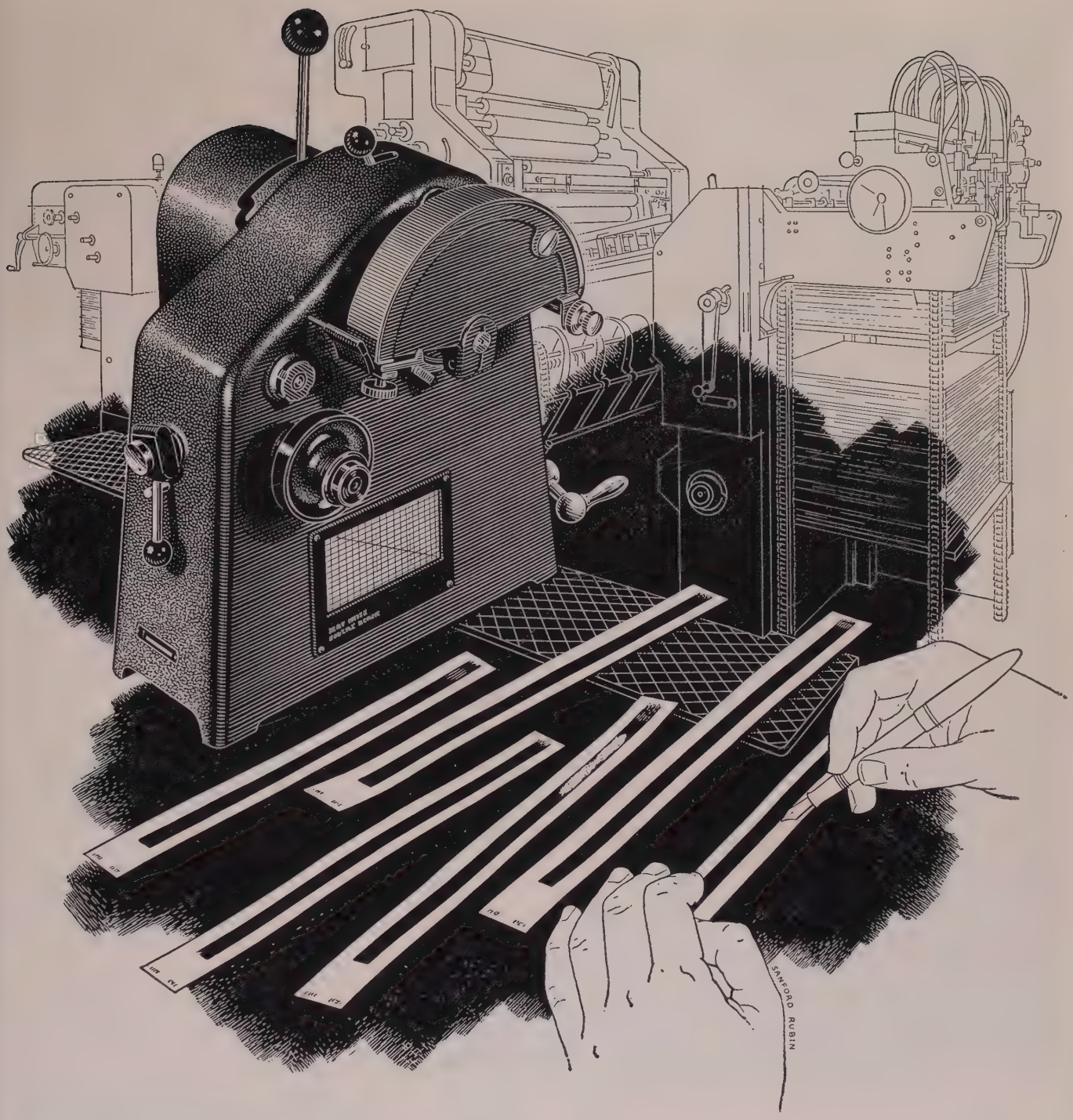
Reservations for sleeping accommodations should be made directly with the Panthind Hotel, Grand Rapids, Mich.

Fifteenth Engineering Conference

The TAPPI Fifteenth Engineering Conference will be held at the Robert Meyer Hotel, Jacksonville, Fla., on Oct. 23–27, 1960.

M. J. Osborne, Bowaters Southern Corp., Calhoun, Tenn., chairman of the Engineering Division is general conference chairman. V. P. Owens, Combustion Engineering, Inc., New York, N. Y., secretary of the Division is technical program chairman.

J. B. Peebles, Jr., General Electric Co., Jacksonville, Fla., is chairman of the Local Arrangements Committee. His committee has been organized as follows:



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The I.G.T. printability tester closely approximates the tremendous pounding and demands today's high-speed presses make on papers. Results of these tests consistently show Stayco Starches improve pick resistance . . . smoothness of printing surface . . . ink penetration rate and sheet strength, to meet these most rigid requirements.

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M. J. Osborne, Bowaters Southern Paper Corp.

V. P. Owens, Combustion Engineering, Inc.

Advisory: L. C. Crowder, St. Regis Paper Co., Jacksonville, Fla.
Secretary: Mrs. Harold Collins, General Electric Co., Jacksonville, Fla.
Registration: C. W. Page, St. Regis Paper Co.; H. W. Evans, St. Regis Paper Co.
Hotel Arrangements: J. E. Baber, T. C. Heyward Co., Charlotte, N. C.; R. F. Sorenson, St. Regis Paper Co.
Hospitality: A. J. Stockslajer, Reliance Electric and Engineering Co., Jacksonville, Fla.; J. B. Chandler, John B. Chandler Co., Atlantic Beach, Fla.; P. L. Poland, General Electric Co.; J. T. Vincent, General Electric Supply Co., Jacksonville, Fla.; A. McDowell, Allis Chalmers Mfg. Co., Jacksonville, Fla.; D. Barnes, Westinghouse Electric Co., Jacksonville, Fla.; W. Clements, Combustion Engineering Co., Jacksonville, Fla.; R. V. Pennington, Owens-Illinois Glass Co., Jacksonville, Fla.
Printing: F. A. Adams, Owens-Illinois Glass Co.
Publicity: R. E. Phillips, St. Regis Paper Co.
Mill Tours: H. Westberry, Owens-Illinois Glass Co.

Mrs. L. C. Crowder is Ladies' Program chairman and Mrs. J. B. Peebles, Jr., is secretary. Other ladies' program committee members are Mesdames W. B. Hobbs, H. R. Emery, R. F. Sorenson, F. A. Adams, and J. E. Baber.

The technical program of the conference will consist of 16 sessions beginning on Monday morning, October 24, and continuing through Thursday, October 27. Tuesday afternoon, October 25, is open for those who wish to go on mill tours. A banquet will be held Wednesday evening.

For those who wish to make their hotel reservations early may do so by writing to the following address:

TAPPI 15th Engineering Conference
Hotel Robert Meyer
Jacksonville, Fla.

and state the day and time of both arrival and deparature. Confirmation will be made by the hotel directly to the individual requesting the reservation.

Fourteenth Alkaline Pulping Conference

The 14th Alkaline Pulping Conference will be held Aug. 22–24, 1960, at the Multnomah Hotel in Portland, Ore.

D. Wetherhorn, Continental Can Co., Port Wentworth, Ga., chairman of the Alkaline Pulping Committee is general conference chairman. P. H. West, Thilmany Pulp and Paper Co., Kaukauna, Wis., vice-chairman of the Alkaline Pulping Committee's portion of the program. P. J. Frost, Crown Zellerbach Corp., Camas, Wash., is technical program chairman for the Sulfite Committee's portion of the program.

A. H. Wickett, Weyerhaeuser Timber Co., Longview, Wash., is local arrangements chairman and he is being assisted by K. M. Shold, Crown Zellerbach Corp., Port Townsend, Wash.

There are to be four technical sessions, three of which will be on alkaline pulping and the fourth will be on sulfite pulping. In the past several alkaline pulping conferences, the Semichemical Pulping Committee has been invited to participate by providing technical papers for one of the four sessions. This year, with the merger of the Semichemical Pulping Committee and the Acid Pulping Committee forming the Sulfite Pulping Committee, it is this new committee which has been invited to participate.

Early evidence points to the development of a very strong technical program by Messrs. West and Frost.

Plans are underway to provide those attending the conference with excellent opportunities to visit some of the large pulp and paper mills in the vicinity of Portland.

Sunday, October 23

10:00 a.m.	*Local Arrangements (English Room)*
2:00–6:00 p.m.	*Committee Consultations (Essex Room)*
4:00 p.m.	*Process Instrument Steering (French Room)*
4:00 p.m.	*Electrical Steering (Spanish Room)*
4:00 p.m.	*Maintenance Steering (Oxford Room)*
1:00–8:00 p.m.	*Registration (Mezzanine)*
9:00 p.m.	*Div. Staff (Dover Room)*

Monday, October 24

9:00 a.m.	*Session I—General (Windsor North)*
9:15 a.m.	*Session II—Electrical (Windsor North)*
9:15 a.m.	*Session III—Chem. Engr. I (Process) (Windsor South)*
12:30 p.m.	*Luncheons*

Drying (Essex)
Engr. Economics (Oxford)
Maintenance Engr. (Dover)
Mechanical Engr. (French)

2:00 p.m.	*Session IV—Fluid Mechanics I (Windsor North)*
	Session V—Chem. Engr. II (Operations Research) (Windsor South)
6:00 p.m.	*Process Instrumentation (French Room)*

Tuesday, October 25

9:00 a.m.	*Session VI—Drying I (High Velocity Air) (Windsor North)*
9:00 a.m.	*Session VII—Maintenance (Windsor South)*
12:30 p.m.	*Luncheons*

Chemical Engr. (Essex)
Civil Engr. (Oxford)
Electrical (Dover)
Fluid Mechanics (French)

2:00 p.m.	*Mill Tours*
2:00 p.m.	*Sanitary Engineering Committee (Dover Room)*

J. B. Peebles, Jr. General Electric Co.

D. Wetherhorn, Continental Can Co.

340 TONS PER DAY

...MgO Plant On Line At Alaska Lumber & Pulp, Sitka

With the start of the 340 ton per day Alaska Lumber & Pulp Company plant, over 650,000 tons of pulp per year are being produced by the MgO Process.

This is the second* magnesia bi-sulfite dissolving pulp mill in Alaska, and the largest industrial improvement since statehood. Utilizing the commercially-proved, closed cycle MgO Recovery Process, Sitka's predicted chemical usage is 20 lb of MgO and 50 lb of sulfur per ton of unbleached pulp.

Two B&W recovery boilers, each designed to process 550,000 lb of waste sulfite liquor solids per day, generate a combined total of 228,000 lb of steam per hour. Two B&W power boilers provide supplemental steam for power and process to 320,000 lb per hour burning bark or oil singly or in combination.

The MgO Process provides economical recovery of chemicals and heat from the waste sulfite liquors. In addition, air pollution and process odors are reduced to an absolute minimum. The Babcock & Wilcox Company, Boiler Division, Barberton, Ohio.

***Sitka** *is the fifth MgO plant built in recent years in the continental U. S. Others are Weyerhaeuser Timber Company, Longview, Washington; Ketchikan Pulp Company, Ketchikan, Alaska; Weyerhaeuser Timber Company, Cosmopolis, Washington; Brown Company, Berlin, New Hampshire. A sixth plant is on order for Hylite Bruks in Sweden.*

P-826

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BOILER DIVISION

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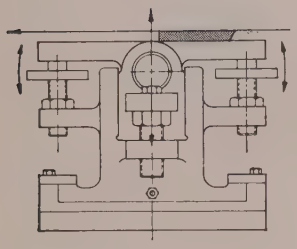

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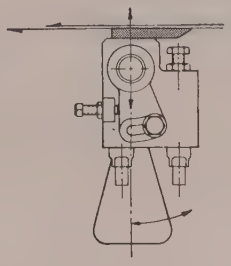

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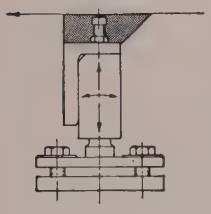

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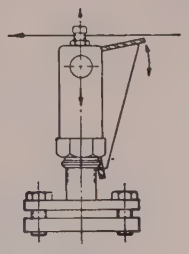

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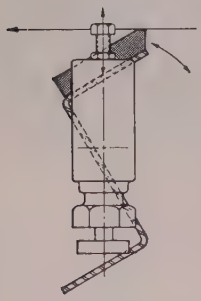

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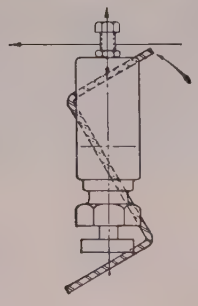

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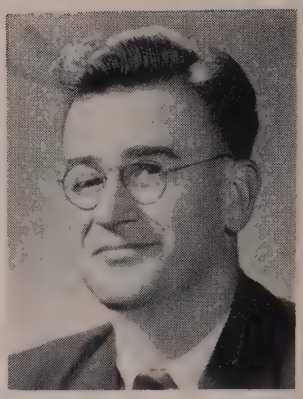

P. J. Frost, Crown Zellerbach Corp.

4:00 p.m. — *Engr. Data Sheet (English Room)*

Wednesday October 26

9:00 a.m. — *Session VIII—Mechanical Engr. (Windsor North)*
9:00 a.m. — *Session IX—Civil Engr. (Windsor South)*
9:00 a.m. — *Session X—Drying (Radiant Drying) (Essex, Dover, Oxford)*
12:30 p.m. — *Luncheons*

Steam & Power (Essex Room)
Industrial Engr. (Dover Room)
Corrosion (Spanish Room)
Operations & Research (French Room)

2:00 p.m. — *Session XI—Engr. Economics (Windsor North)*
2:00 p.m. — *Session XII—Sanitary (Essex, Dover)*
2:00 p.m. — *Session XIII—Fluid Mechanics II (Windsor South)*
6:00 p.m. — *Cocktail Hour (Mezzanine)*
7:00 p.m. — *Banquet (Windsor No. & So., Essex, Dover, Oxford)*

Thursday, Oct. 27

9:00 a.m. — *Session XIV—Steam & Power (Windsor North)*
9:00 a.m. — *Session XV—Corrosion I (Windsor South)*
9:00 a.m. — *Session XVI—Industrial (Essex, Dover, Oxford)*
2:00 p.m. — *Session XVII—Process Instrumentation (Windsor North)*
2:00 p.m. — *Session XVIII—Corrosion II (Windsor South)*
6:00 p.m. — *Engr. Div. Staff Dinner (Essex, Dover)*

Ladies' Headquarters, Sunday through Thursday Executive Suite (Room 502)

U. S. Forest Products Laboratory

The Golden Anniversary of the U. S. Forest Products Laboratory, oldest research organization of its kind in the world, will be observed June 2–4 at Madison, Wis., where the trail-blazing institution was founded 50 years ago.

Plans for the celebration, expected to bring hundreds of friends, "alumni," and well-wishers to Madison, are rapidly taking final form, according to Director Edward G. Locke. The 3-day affair, he said, will be touched off with a banquet Thursday evening, June 2. At a general meeting of Laboratory staff and guests Friday morning, key leaders in industry, government, and education will speak on various facets of research, past and future. And on Friday afternoon guests

will tour the Laboratory to view special exhibits and witness dedicatory ceremonies.

All day Saturday, the Laboratory staff will hold open house for the public. "While Saturday isn't a workday for us," Director Locke explained, "we feel that more people will be free to visit with us on that day, and so our doors will be open to all who care to come."

The pioneer Laboratory was dedicated June 4, 1910, to a career of public service which, Dr. Locke pointed out, has yielded rich returns to both producers and consumers of a multitude of wood products. High among its achievments he listed such industrial advances as:

1. New pulping processes for species once thought to be useless forest "weeds."
2. Basic production and engineering discoveries that helped launch the nation's house-prefabrication and timber-laminating industries.
3. Kiln drying and other wood seasoning processes that swiftly and safely remove excess sap from many millions of board feet of lumber annually.
4. Preservatives and processes used by industry to immunize huge quantities of wood against decay and fire.
5. Packaging research that has greatly reduced shipping costs and losses during peace and war.

Cooperative efforts of the University of Wisconsin and the Forest Service, U. S. Department of Agriculture, brought the Laboratory into existence. Forest Service research on wood had been going on for a few years under agreements with a number of universities from New England to California. But it had quickly become obvious that better organization and closer contacts between workers were needed on the various projects.

Proposals to build a laboratory for forest products research were turned down, however, by Congress. This led to a canvass of various universities by Forest Service officials, then headed by Chief Forester Gifford Pinchot. Several schools made concrete proposals of aid and cooperation. The best one came from President Charles Van Hise, conservation-minded president of the University of Wisconsin, whose Board of Regents authorized an offer that included a new building complete with heat and power.

Construction of the building was begun in 1909, and during that year the Forest Service began pulling its research teams in to Madison from their various scattered locations. By the time the building was dedicated, about 45 scientists, engineers, and their helpers were on hand to staff the fledgling institution.

"It was indeed a new kind of venture in scientific research," points out Dr. Locke, "because the very concept was new and untried. Heretofore, scientific research had remained pretty well channeled in its traditional courses—physics, chemistry, botany, biology, and the other pure sciences. In this new laboratory they were all being brought together to contribute

McGarvey Cline, 1910–1912

H. F. Weiss, 1912–1917

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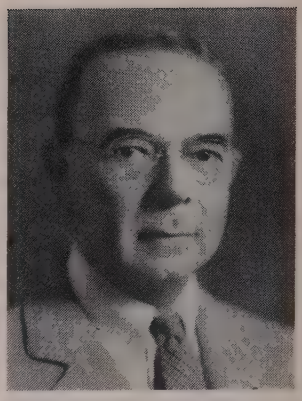


C. P. Winslow, 1917–1946

Through the years, the founders' organization concept of the Laboratory has been largely retained. Physicists, engineers, and mathematicians have combined skills on strength and construction research. Chemists have been employed on research on the chemical nature of wood, and—working with chemical engineers, technologists, mathematicians, and pathologists—on pulp and paper research, preservation, fire prevention, adhesive bonding, and paints. Foresters pool talents with botanists and engineers to explore wood structure and growth under the microscope and in the woods.

The new laboratory did not remain unique in the world for long. During the very first decade of its existence, spurred by the needs of a nation embroiled in a world war, it demonstrated its capabilities beyond anyone's quibbling.

When supplies of seasoned lumber grew short, a new kind of dry kiln was devised by Laboratory physicists to turn out lumber for cannon wheels, military barracks, and those new-fangled aeroplanes faster and better than ever before.

When airplane designers asked for lighter, stronger wings and fuselages, Laboratory engineers came up with the revolutionary concept of "stressed-skin" construction. And to make it work, Laboratory chemists developed glues with the unheard-of resistance to water, to bond the plywood skins to the wooden frames.

And thus it went. Whatever the problem, scientific teams combining skills of various traditional sciences pooled their know-how for answers. It rapidly became proved beyond doubt that many problems of wood research were common to several branches of science. The physicist trying to remove water from wood and the chemist trying to put preservatives in were up against the same fundamental task of studying the movement of liquids and vapors through the microscopically small openings in wood structure. The engineer doing research on wood's strength needed the help of the botanist schooled in wood structure and growth. And so on.

Congress recognized the expanding importance of forest products research in 1930 by voting funds for a new and much larger building. Erected on land made available by the University, this building was opened in 1932.

The rest of the world has not been slow, Dr. Locke pointed out, in recognizing the potential of this new type of scientific organization. Forest products laboratories, under one name or another, are now well established in many countries around the world. A number operated by States, educational institutions, and private industry flourish in the United States.

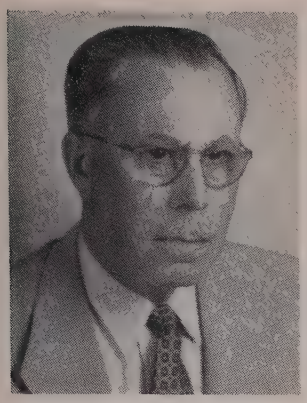
"I am happy to say," Dr. Locke observed, "that nationwide and worldwide, we're pretty much a closeknit research family. We of the Madison Lab. enjoy cordial relations with our fellow research workers in this country and abroad. And there have been some remarkable international instances of close collaboration on research problems to highlight the interchange of our findings."

Among the thousands of visitors who come to the Laboratory annually for technical discussions and meetings are hundreds from abroad. In 1959, 294 came from 49 foreign countries.

Throughout its half-century history, the Laboratory has cooperated closely with industry groups. Staff members take numerous committee assignments in such organizations as the American Society for Testing Materials, the Forest Products Research Society, the Technical Association of the Pulp and Paper Association, the American Chemical Society, and the American Wood-Preservers' Association. These organizations help disseminate results of the Laboratory research in the form of quality standards voluntarily adopted by industry, industry-devised grading rules for various wood products, and design and production requirements.

G. M. Hunt, 1946–1951

Industrial concerns and associations also support special research projects at the Laboratory. Such work is accepted if generally



J. A. Hall, 1951–1959

useful results are likely to be obtained.

A parallel service is given other agencies of government. The Laboratory is the designated authority for wood identification among federal agencies and furnishes this service free to the public. It works closely with such groups as the Army, Navy, and Air Force in drawing up specifications, handbooks, manuals, and the like as well as conducting research on Department of Defense problems through cooperative arrangements.

The half-century span of the Laboratory's existence, Dr. Locke remarked, has coincided with the world's emergence from "the horse-and-buggy age into the age of rockets." The Laboratory's research program has been likewise transformed, contributing not only "better seasoned wood for wheelwrights but more dependable nitrocellulose propellants for space vehicles," he emphasized.

Special exhibits at the Golden Anniversary celebration are planned to demonstrate the progress of Laboratory research from its beginnings to the present. Examples of both fundamental and applied research will be illustrated.

"While much of the Laboratory's work," Dr. Locke observed, "has proved of great dollars-and-cents benefit to the nation, you cannot put a dollar sign on the true value of research. Fundamental explorations today chart the paths industry will follow tomorrow in bringing new or improved forest products to market. How can one put a money value on, say, a discovery shedding light on the true composition of lignin—a discovery that can affect wood utilization in so many different fields? Yet such discoveries are the legitimate goals of scientific research—and ultimately the most valuable ones."

One of the benefits that is is hoped will result from the June gathering, the director said, is a broad assessment and reappraisal of forest products research goals.

"Scientists," he commented, "are not in the habit of looking backward. An occasion such as this, though, gives us unusual reason to reflect upon what has been done and what needs doing. We are inviting our friends from other laboratories, from industry, and from the schools and colleges to join with us in such reflections and exchanges of viewpoints."

Dr. Locke, the Laboratory's sixth director in its 50-year history, took office last year as successor to Dr. J. A. Hall. The Laboratory's first director was McGarvey Cline, who was succeeded in 1912 by his assistant, Howard F. Weiss. In 1917 Carlile P. Winslow started by far the longest tenure in office, remaining until 1946. He was succeeded by George M. Hunt who moved up from the post of chief of the division of wood preservation. Hunt retired in 1951, when Dr. Hall took over.

Cline and Weiss have been credited with conceiving the idea of establishing a forest products laboratory in cooperation with a university. The two Forest Service research engineers won official support for the plan from Pinchot. When Cline went to Madison as the first director, Weiss went along as assistant director. Among others joining them there was Winslow. In 1913 Hunt came to the Laboratory from other research duties in the Forest Service.

E. G. Locke, 1959–

Indicative of the youthfulness of the men who launched the Laboratory and directed its course in its first half century is the fact that all ex-directors but one still live. Weiss died in 1940. Cline resides in Jacksonville, Fla., and Winslow in Washington, D. C. Hunt, since his retirement, has spent most of his time in the Philippines, helping that young nation establish and operate a forest products laboratory. Dr. Hall is a consultant to forest products manufacturers in Portland, Ore.

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TAPPI NOTES

Highlights of Executive Committee Minutes

A petition for a local section charter from the Golden Gate District of the Pacific Section was unanimously approved by the Executive Committee and the Local Sections Operations Committee. The presentation ceremony will be held in Berkeley on May 17, at the time of the Robert True Memorial meeting.

The 1960 Association budget forecasts both income and expenses of slightly over $800,000. During 1959, TAPPI's current income exceeded operating expenses for the first time in three years, owing largely to record levels of dues and advertising income.

The Headquarters staff has been realigned with P. E. Nethercut named as Executive Secretary to direct all staff operations. R. G. Macdonald has been appointed Treasurer and Editorial Director. A. J. Winchester was selected as Technical Secretary to coordinate all technical division activities, and J. W. Field was named Local Sections Assistant, with similar responsibilities for the local sections and districts.

TAPPI's local section rebate policy has been delineated to permit all sections to receive rebates on same basis. Each local section is authorized to request a $2 rebate for each national member who receives some service from that section, provided the member's rebate is not requested by another section having, in the opinion of the Executive Secretary, a more appropriate claim.

Twenty-five years of TAPPI-sponsored research programs have been completed this year. Since 1935 the Association has spent $522,000 on 142 committee projects. A special report on these programs will be prepared by the staff and J. L. Parsons, chairman of the Project Appropriations Committee, during this entire period.

A 1960 APPA-TAPPI Research Conference has been scheduled, and a $3000 grant for this meeting was authorized by the Executive Committee. Like previous conferences of this type it will bring chemistry and engineering professors together with paper industry technical leaders to discuss research problems of mutual interest.

Approval was given to a request from the Joint Career Guidance Committee for a TAPPI contribution of $1000 to the Committee's working fund. This Committee, composed of representatives from TAPPI, APPA, PIMA, NPA, and NPTA, will coordinate the recruiting activities of the various paper industry associations.

Association services to corporate members will be expanded. All corporate members are to receive bound volumes of the *Tappi* Technical Sections each year, and incoming corporate members will receive a complete set of Standards, Data Sheets, Routine Control Methods, and the most recent TAPPI Bibliography during the first year of their memberships.

An intensified member relations program will be inaugurated. The primary objectives of this program are recognition of the accomplishments of TAPPI members in Association activities, support of these activities by paper industry managements, and understanding of the Association's policies by its own members. The Association will have the services of Fuller, Miele, Inc., as outside counsel in these activities.

The appointment of members to TAPPI special committees has been made by President J. R. Lientz. Of these there are three committees whose chairmen are particularly anxious to receive appropriate suggestions from the Association's membership.

The first is the *Membership Services Committee* under the chairmanship of H. M. Annis, Oxford Paper Co., New York, N. Y. This committee will review present and proposed Association services to each class of TAPPI members and recommend whatever changes seem desirable.

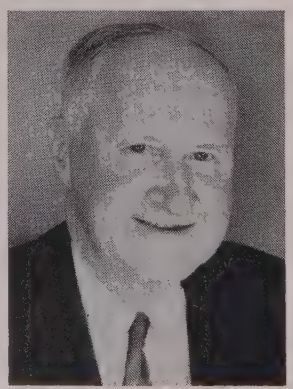
The *Nominating Committee,* with E. H. Olmstead, Eaton-Dikeman Co., Mt. Holly Springs, Pa., as chairman, will prepare a slate of candidates for the 1961 offices of President and Vice-President, and for the four new Executive Committee members.

The *Awards Committee,* led by P. S. Cade, Harding-Jones Co., Middletown, Ohio, will recommend candidates for the 1961 TAPPI Medal.

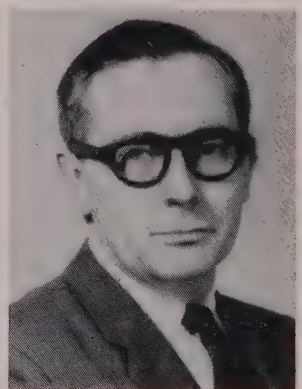
Suggestions may be sent directly to the appropriate chairman or to the headquarters office for transmittal to the committee.

PHILIP E. NETHERCUT

P. E. Nethercut



R. G. Macdonald



A. J. Winchester

J. W. Field

PERSONAL MENTION

New TAPPI Members

Jose B. Avarez M., General Director, Compania "PRIMUS" del Uruguay, S. A.

Clyde B. Anderson, Technical Assistant to Superintendent, Inland Empire Paper Co., Millwood, Wash., a 1949 graduate of University of Washington.

Neil L. Anderson, Manager, Industry Sales Development, Acme Steel Co., Chicago, Ill. Attended Northwestern College.

Aldo Barzaghi, Vice-President, S.p.A. Industrie Chimiche Barzaghi UFA, Milano, Italy.

Caetano Belliboni, Technical Director, Adams Do Brasil, S. A., Sao Paulo, Brazil, a 1944 graduate of Polytechnic Institute, Sao Paulo.

Laurence P. Benedict, Coatings Sales Representative, The Dow Chemical Co., Boston, Mass., a 1950 graduate of Brown University.

Lauren R. Berry, Process Engineer, Western Precipitation Div., Joy Manufacturing Co., Los Angeles, Calif., a 1953 graduate of the University of Missouri.

Scott E. Berry, Senior Chemist, Robert Gair Div., Continental Can Co., Haverhill, Mass., a 1957 graduate of Northeastern University.

Peh Teik Bin, Chemist, Forest Research Institute, Kepong, Selangor, Malaya, a 1959 graduate of Northern Polytechnic Institute, London.

Louis H. Bock, Manager, Research Div., Rayonier Canada Ltd., Vancouver, B. C., Canada, a 1928 graduate from Kansas State College with a Ph.D. degree in 1931 from University of Illinois.

Raymond W. Boyer, Chemist, Joseph Bancroft & Sons Co., Wilmington, Del., a 1953 graduate of University of Delaware.

William D. Brand, Engineering Supervisor, Cutler-Hammer, Inc., Milwaukee, Wis., a 1947 graduate of Kenyon College.

Herward Braunegg, Technical Service Director, Papierfabrik Scheufelen, Oberlenningen, Wurttemberg, Germany, a 1950 graduate of Technical University.

Emery Brugh, Paper Control, Time, Inc., New York, N. Y.

Henrik H. Bruun, Acting Professor, University Abo Akademi, Abo, Finland, 1954 graduate of Abo Akademi University with a Dr. of Technology degree.

William M. Burr, Jr., Sales Representative, Dewey & Almy Div., W. R. Grace Co., Cambridge, Mass., a 1952 graduate of University of Missouri.

A. D. Chaudhari, Director, West Coast Paper Mills, Ltd., Bombay, India, a 1923 graduate of Technical University, Altenburg, Germany.

Kenneth M. Cherry, Vice-President, Manufacturing, Owens-Illinois, Mill Div., Toledo, Ohio, a 1924 graduate of Westminster College.

John P. Clardy, Paper Technologist, Champion Paper and Fibre Co., Canton, N. C., a 1959 graduate of North Carolina State College.

John G. Coats, Jr., Staff Engineer, Paper Div., Bowaters Engineering and Development. Inc., Calhoun, Tenn., a 1944 graduate of Alabama Polytechnic Institute.

Joseph C. Coulter, Technical Sales Service, Anheuser-Busch, Inc., St. Louis, Mo., a 1948 graduate of St. Louis University.

Arthur T. Davies, Deputy Manager, Sudbrook Pulp Mill Ltd., Sudbrook, Chepstow, Monmouthshire, England, a 1949 graduate of Liverpool University.

Charles R. Daving, Salesman, Hooker Chemical Corp., Niagara Falls, N. Y., a 1943 graduate of Capital University.

Raymond L. Delaney, Technical Director, Simplex Paper Corp., Adrian, Mich., a 1952 graduate of University of Toronto.

Horacio Diaz Ch., Chemical Engineer, W. R. Grace Co., Paramonga Paper Mill, Paramonga, Peru, a 1948 graduate of Universidad Nec, Trujillo.

Daniel S. Dixler, Senior Chemist, Air Reduction Co., Inc., Murray Hill, N. J., a 1938 graduate of Brooklyn College.

Charles R. Dolecki, Jr., Quality Control Supervisor, The Hamersley Mfg. Co., Garfield, N. J., a 1959 graduate of Newark College of Engineering.

Peter J. Eberth, Engineer, Fabrica Nacional De Papel Tissue, Ltd., Santiago, Chile, holder of National Certificate Mechanical Engineering, Liverpool, England.

Joseph B. Farrell, Group Manager, Research and Development, American Machine and Foundry Co., Springdale, Conn., a 1943 graduate of Notre Dame College, with a Ph.D. degree in 1954 from Cornell University.

Austin W. Fisher, Jr., Vice-President, Director of Research, Ludlow Papers, Inc., Needham Heights, Mass., a 1937 graduate of the University of Massachusetts.

Joe B. Fleming, Jr., Market Research, Fleming & Sons, Inc., Dallas, Tex.

John G. Frye, Salesman, Stoney-Mueller, Inc., Lyndhurst. N. J., a 1937 graduate of Lafayette College.

D. Donald Gagliardi, Research Director, Gagliardi Research Corp., East Greenwich, R. I., a 1942 graduate of Yale University.

Sidney W. Galloway, Vice-President, The Rust Engineering Co., Pittsburgh, Pa. Attended Carnegie Institute of Technology.

Ronald H. Gerstenberger, Pulp Mill Design Coordinator, Chas. T. Main, Inc., Boston, Mass.

Charles C. Goodwin, Instructor of Chemical Engineering, University of Maine, Orono, Me., a 1958 graduate of University of Maine.

Douglas C. Grant, Salesman, Penick & Ford Ltd., Inc., New York, N. Y., a 1938 graduate of University of Maine.

James M. Harper, Research Chemist, Albemarle Paper Manufacturing Co., Richmond, Va., a 1955 graduate of N. Y. State College of Forestry.

John R. Haug, Project Manager, Jackson & Moreland, Inc., Boston, Mass. a 1940 graduate of University of Pennsylvania.

Robert L. High, Director of Research, Keever Starch Div., National Industrial Products Co., Columbus, Ohio, a 1949 graduate of University of Cincinnati.

Harold T. Hixon, Technical Director, Chillicothe Paper Co., Chillicothe, Ohio, a 1936 graduate of Kenyon College.

Don T. Ho, Librarian, Minnesota Mining & Mfg. Co., St. Paul, Minn.

Kurt Hottenroth, Works Manager and Technical Advisor, Orient Paper Mills, Ltd., Calcutta, India, a 1936 graduate of University of Heidelberg with a Ph.D. degree.

Nestor Iparraguirre T., Industrial Chemist, W. R. Grace Co., Paramonga, Peru, a 1943 graduate of Universidad Nec., San Marco.

Hideo Ishioka, Chief of Technical Section, Daishowa Paper Mfg. Co., Ltd., Hokkaido, Japan. Attended Taga Technical College.

Joseph H. Kellner, Sales Representative, H. Waterbury & Sons Co., Oriskany, N. Y.

H. E. Kirkland, Instrument Engineer, Bowaters Engineering and Development, Inc., Calhoun, Tenn., a 1954 graduate of Alabama Polytechnic Institute.

C. J. J. E. Klep, Mechanical Engineer, Ned. Exportpapierfabriek N. V., Nijmegen, Holland, a Mechanical Engineer graduate of 1957.

Thomas M. Knight, Plant Engineer, Great Northern Paper Co., East Millinocket, Me.

Osamu Koike, Industrial Machinery Section, Marubenilida Co., Ltd., Ohtemachi, Chiyoda-ku, Tokyo, Japan, a 1949 graduate of Hosei University.

Shigeru Kono, Chief of Engineering Dept., Daishow Paper Mfg. Co., Ltd., Shizuoka Pref., Japan. Attended Osaka Municipal Technical School.

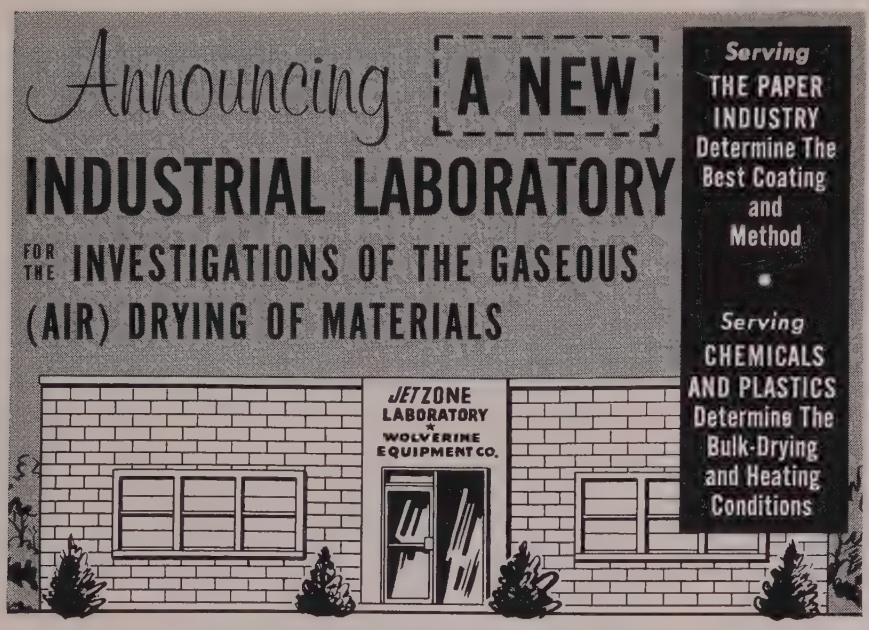
Charles R. Lammers, Manager, Industry Sales Development, Acme Steel Co., Chicago, Ill., a 1939 graduate of University of Illinois.

Nicholas J. Lardieri, Engineer, National Council for Stream Improvement, New York, N. Y., a 1949 graduate of Purdue University with a Ph.D. degree in 1953.

Edward M. Lavery, Technical Sales Service, Anheuser-Busch, Inc., St. Louis, Mo., a 1950 graduate of Kent State University.

Paul C. Lemmerman, Technical Service Representative, E. I. du Pont de Nemours & Co., Inc.. Cleveland, Ohio, a 1928 graduate of Oberlin College.

Fernando Leniz, Production Vice-President, Compania Manufacturera de Papeles y Cartones, S. A., Santiago, Chile, a 1948 graduate of University of Chile.



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William C. Lowe, Research Librarian, Haloid Xerox, Inc., Rochester, N. Y.

Giancarlo Lucchini, Manager, Industrial Engineering Dept., Ercole Marelli & C. S. p. A., Milano, Italy, a 1946 graduate of Politecnico of Milan.

Emily C. Lumbard, Librarian, Hexcel Products, Inc., Berkeley, Calif.

Lloyd R. McCoy, Manager, Sales-Service, Diamond Alkali Co., Cleveland, Ohio, a 1933 graduate of Muskingum College.

Robert L. McDowell, Research Chemist, Research & Development Div., American Viscose Corp., Marcus Hook, Pa., a 1943 graduate of St. Joseph's College.

John P. McGowan, Librarian, Franklin Institute, Philadelphia, Pa., a 1949 graduate of Hunter College.

William H. Mehaffey, Sales Manager, Hydraulic Machinery, Co., Ltd., Montreal, Canada, a 1950 graduate of McGill University.

Eston E. Melton, Jr., Process Engineer, Union Bag-Camp Paper Corp., Savannah, Ga., 1958 graduate of University of Florida.

Richard H. Miller, Base Development Supervisor, E. I. du Pont de Nemours & Co., Inc., Rochester, N. Y., a 1950 graduate of Princeton University.

John Mirza, Director of Chemical Research & Development, Miles Chemical Div., Miles Laboratories, Inc., Elkhart, Ind., a 1944 graduate of DePauw University, with a Ph.D. degree in 1949.

Bernard L. Mocquart, General Manager, Prochim S. A., Douat, Nord, France.

Otto Model, Assistant General Manager, Model A. G., Weinfelden, Switzerland, a 1955 graduate of Handel College, St. Gallen.

Reeve C. Morehouse, Supervising Engineer, Bechtel Corp., San Francisco, Calif., a 1941 graduate of Massachussets Institute of Technology.

Henry T. Murphy, Librarian, Purdue University, Lafayette, Ind., a 1948 graduate of Boston University.

Robert J. Murphy, Plant Manager, Continental Can Co., Teterboro, N. J., a 1949 graduate of Newark College of Engineering.

Fortunato De Orbegoso, Production Superintendent, W. R. Grace & Co., Lima, Peru, a 1948 graduate of Universidad Nacional de la Libertad.

Raymond F. Ostrander, Factory Manager, U. S. Playing Card Co., Cincinnati, Ohio, a 1933 graduate of Pace College.

Robert B. Otto, Service Representative, Hercules Powder Co., Milwaukee, Wis., a 1959 graduate of Michigan College of Mining & Technology.

Anthony A. Pataky, Research Chemist, Central Research Div., Abitibi Power & Paper Co., Ltd., Sault Ste. Marie, Canada, a 1951 graduate of Technical University of Budapest.

Charles D. Pauli, Manager, Quality Control, Commercial Solvents Corp., New York, N. Y., a 1938 graduate of Bradley University.

John B. Peebles, Jr., Sales Engineer, General Electric Co., Jacksonville, Fla., a 1934 graduate of Emory University.

Girard W. Phelps, Vice-President & Technical Director, United Clay Mines Corp., Trenton, N. J., a 1937 graduate of University of Alabama.

Paul A. Plasse, Chemist, Arthur D. Little, Inc., Cambridge, Mass., a 1952 graduate of Colby College.

Brian W. Power, Vice-President, Manufacturing, The E. B. Eddy Co., Hull, P. Q., Canada.

N. F. Prati, Plant Engineer, Barrett Div., Allied Chemical Corp., San Antonio, Tex., a 1950 graduate of Syracuse University.

Gordon U. Proctor, Associate Partner, Proctor & Redfern, Toronto, Canada, a 1947 graduate of the University of Alberta.

John H. Prout, Salesman, Acme Steel Co., Chicago, Ill. Attended Northwestern College.

Speed U. Reavis, Jr., Consultant, Industrial Consulting & Appraisal Co., Little Rock, Ark., a 1934 graduate of University of Arkansas.

Leo R. Rift, Librarian, Southern Illinois University Library, Carbondale, Ill., a 1952 graduate of University of Denver.

Richard R. Roberts, Chemical Engineer, Itek Corp., Boston, Mass., a 1939 graduate of Tufts University.

Paul M. Rooney, Head, Technology Dept., Buffalo & Erie County Public Library, Buffalo, N. Y., a 1940 graduate of University of Buffalo.

Waldo D. Rouviere, Application Engineer, B-I-F Industries, Inc., Providence, R. I., a 1926 graduate of Bryant College.

Harry F. Schenk, Sales-Service Consultant, Magnus Metal Corp., Fitchburg, Mass.

Robert S. Schnaars, Paper Mill Engineer, Scott Paper Co., Chester, Pa., a 1949 graduate of University of Michigan.

John L. Sheard, Research Chemist, E. I. du Pont de Nemours & Co., Inc., Niagara Falls, N. Y., a 1945 graduate of Harvard University with a Ph.D. degree in 1953.

Bruce D. Skofronick, Staff Chemist, Fox River Paper Corp., Appleton, Wis., a 1959 graduate of University of Wisconsin.

Miroslav Slabina, Head, Paper Research Branch, Pulp and Paper Research Institute, Prague, Czechoslovakia, graduate of the Technical University of Prague.

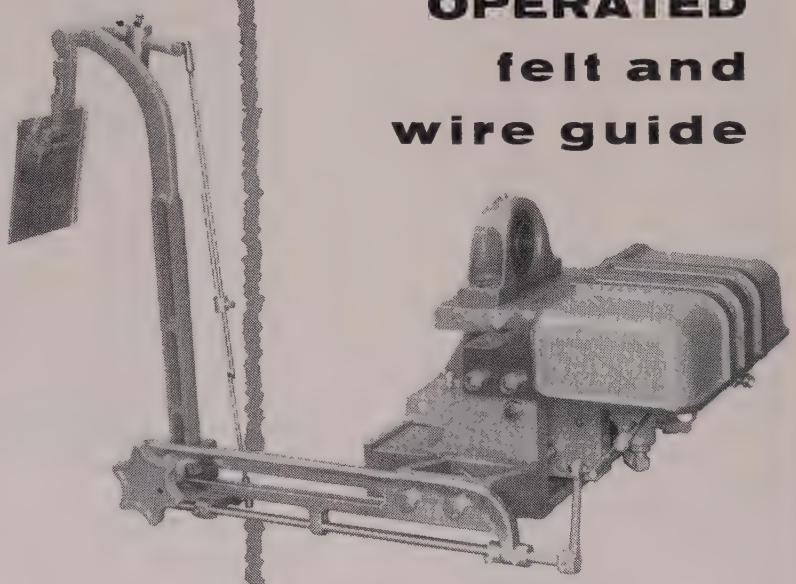
Robert C. Smith, Chemist, Columbia River Paper Mills Inc., Vancouver, Wash., a 1958 graduate of Oregon State College.

Seth M. Snyder, District Manager, Babcock & Wilcox Co., Charlotte, N. C., a 1936 graduate of Ohio State University.

Milton F. Stibal, Technical Trainee, Riegel Paper Corp., Milford, N. J., a 1959 graduate of Western Michigan University.

Andrew M. Swan, Assistant to the Vice-President, Richmond Pulp & Paper Co. of Canada, Ltd., Montreal, Que., Canada, a 1939 graduate of University of Manitoba.

GILBERT and NASH AIR OPERATED felt and wire guide



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John D. Sweeney, Quality Control Supervisor, Continental Can Co., Three Rivers, Mich. Attended Temple University.

Richard H. Tait, Statistician, Champion Paper and Fibre Co., Canton, N. C., a 1952 graduate of North Carolina State College.

Leban W. Trapp, Jr., General Manager, Houston Container Div., St. Joe Paper Co., Houston, Texas. Attended Southern Methodist University.

T. Tromp, Director, N. V. Papierfabriek "GELDERLAND," Nijmegen, Netherlands, a 1925 graduate of Delft College.

Llewellyn B. Tucker, Jr., Trainee, Crane & Co., Inc., Dalton, Mass., a 1954 graduate of New York State College of Forestry.

Gianfranco Vastalegna, Technical Superintendent, Papelera Hurlingham S.A.I.C., Buenos Aires, Argentina, a 1951 graduate of University of Milan.

Simo Vuorilehto, Pulp Mill Superintendent, Enso-Gutzeit Osakeyhtio, Kaukopaa, Vuoksenniska, Finland, a 1955 graduate of Technical University, Helsinki.

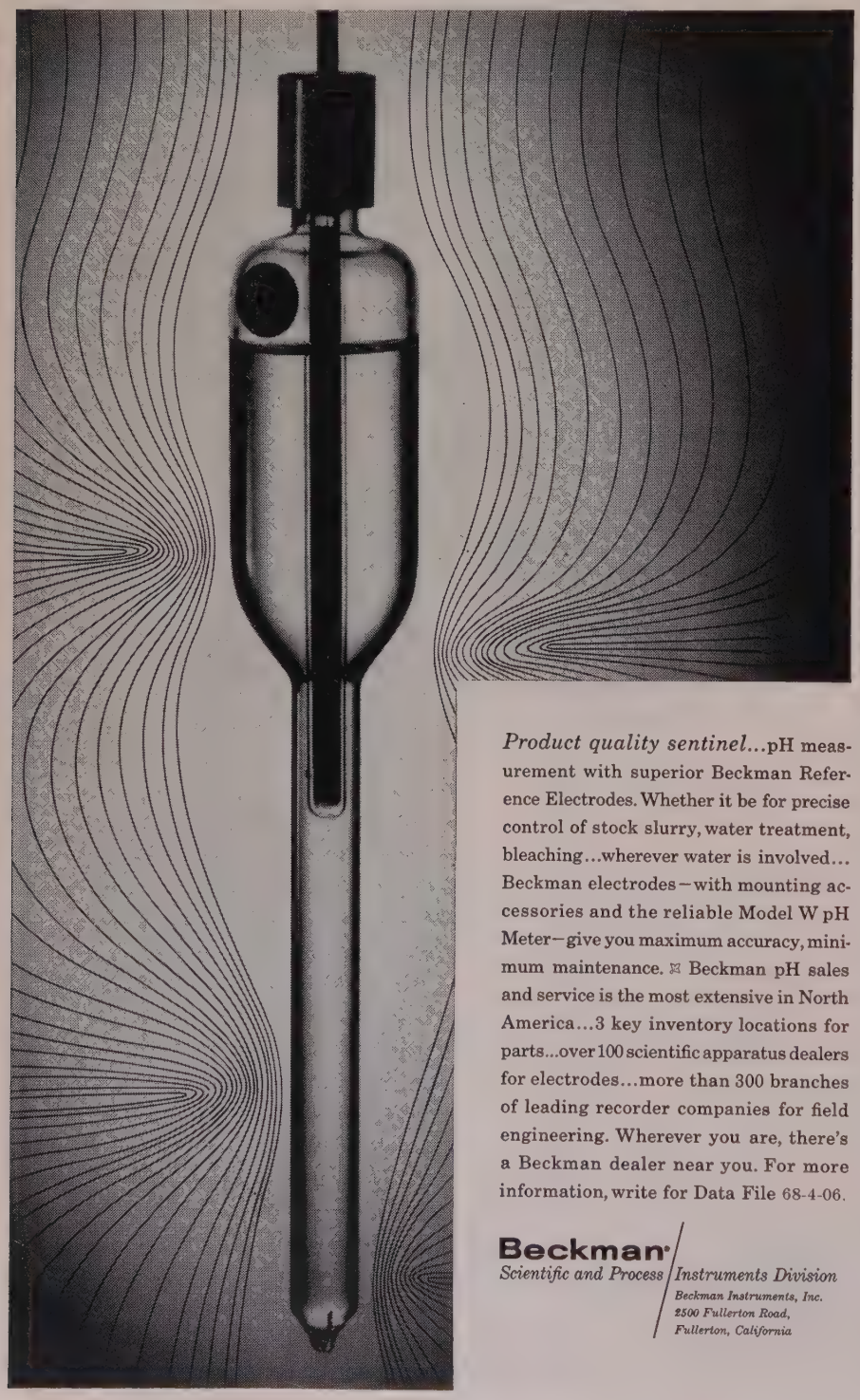
Merle F. Ward, Project Engineer, Noralyn Paper Mills, Inc., Baton Rouge, La. Attended University of Houston.

W. Dale Wegrich, Group Leader, Diamond Alkali Co., Peinesville, Ohio, a 1952 graduate of Baylor University.

Shoichi Yamaguchi, Salesman, Toyo Kikai Kogyo Co., Ltd., Tokyo, Japan, a 1956 graduate of Yokohama City University.

Takeo Yamamoto, Laboratory Engineer, Fujikura Cable Works, Ltd., Tokyo, Japan, a 1948 graduate of Kanazawa College.

Giorgio Zanzi, Mill Manager, Cartiere Ambrogio Binda, Milano, Italy, a 1938 graduate of Politecnico Institute, Milano.



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Appointments

Herman L. Berg, formerly of Sveen-Pederson Sales Corp., is now Manager of Saveall Sales for E. D. Jones Corp., Pittsfield, Mass.

Julian O. Boesinger of the Mead Corp. has been transferred from Sylva, N. C., to Cincinnati, Ohio, as Assistant Director of Board Sales Service.

Sidney G. Briscoe, formerly of Pusey & Jones Corp., is now a Sales Engineer for John Inglis Co., Ltd., Toronto, Ont., Canada.

William T. Butler, formerly of Bauer Bros. Co., is now President and Treasurer of Gallowher Chemicals Canada, Ltd., Lachine, P. Q., Canada.

John G. Casagrande, formerly of Sveen-Pederson Corp., is now a Sales Engineer for E. D. Jones Corp., Pittsfield, Mass.

Richard F. Cashen, Jr., is now Supervisor of Pulp Research for P. H. Glatfelter Co., Spring Grove, Pa.

W. Paul Davenport, application engineer, Pulp and Paper Division, Bailey Meter Co. has been transferred from E. Orange, N. J., to New Orleans, La.

C. George Eisener is now Quality Supervisor for Dryden Paper Co., Dryden, Ont.

William C. Gallagher is now Southern Paper Industry Sales Manager for A. E. Staley Mfg. Co., Charlotte, N. C.

Robert E. Glavin, formerly of Arthur D. Little, Inc., is now a Chemist for Keelox Mfg. Co., Rochester, N. Y.

Henry S. Godshall, Jr., formerly of Marinette Paper Co., is now with Compania Industrial de San Cristobal S/A, Mexico, D. F., Mex.

Karl M. Guest is now Manager of Kraft Pulp and Paper Manufacture for the Brown Co., Berlin, N. H.

Robert G. Guide, formerly of the U. S. Air Force, is now a Chief Project Engineer for Longview Fibre Co., Longview, Wash.

Robert F. Hoban of Sandoz, Inc. has

been transferred from Cincinnati, Ohio, to New York, N. Y., as a Chemist.

Robert A. Jedeikin, formerly of Keuffel & Esser Co., is now in Technical Sales for the American Writing Paper Co., Holyoke, Mass.

Donald E. Johnson, formerly of Superior Paper Products Co., is now a Group Leader in the Research & Development Department of St. Regis Paper Co., Deferiet, N. Y.

Rudolf L. Kutter is now Export Sales Manager for Beloit Iron Works, Beloit, Wis.

Keith E. Lachance, formerly of E. B. Eddy Co., is now Production Manager for Island Paper Mills, Annacis Island, New Westminster, B. C., Canada.

George Lambe, formerly of Gardner Board & Carton Co., is now a Research Chemist for P. H. Glatfelter Co., Spring Grove, Pa.

John Lewis, formerly Head of Paper Engineering Dept., Lowell Technological Institute, is now Technical Director of Pulp & Paper Research Center, Inc., Lawrence, Mass.

Sheridan J. McNamara, formerly of West Virginia Pulp & Paper Co., is now Senior Research Engineer for Huyck Felt Co., Rensselaer, N. Y.

Frederick R. Meyers, formerly of Sveen-Pederson Sales Corp., is now Sveen-Pederson Product Engineer for E. D. Jones Corp., Pittsfield, Mass.

Jack A. Perry, formerly of Weyerhaeuser Timber Co., is now a Sales and Application Engineer for the Dilts Machine Division, Black-Clawson Co., Fulton, N. Y.

James C. Rankin is now National Accounts Manager for the Chemicals-Pigments-Metals Division of the Glidden Co., Cleveland, Ohio.

John C. Redd is now Director of Research and Development for the Mead Corp., Chillicothe, Ohio.

Howard J. Richardson, Sales Engineer of the Monsanto Chemical Co., has been transferred from St. Louis, Mo., to Mobile, Ala.

Rudolph C. Richter, formerly of Marathon Corp., is now Sulfate Pulp Mill Superintendent of the Tasman Pulp & Paper Co., Ltd., Lawerau, New Zealand.

Andrew J. Stiles, Jr., formerly of National Container Corp., is now Superintendent of Mead Containers, Atlanta, Ga.

LeRoy P. Wahl, formerly of Archer Daniels Midland Co., is now Research Chemist for General Mills, Inc., Minneapolis, Minn.

Clarence E. Winchell, Jr., formerly of the Glidden Co., is now Midwest Sales Manager for Moore & Munger, New York, N. Y.

Vernon Woodside of Olin Mathieson Co. has been transferred from New Orleans, La., to Baltimore, Md., as Manager of Heavy Chemicals Sales Development.

Ralph V. Zepp is now Resident Manager of Rayonier, Inc., Jesup, Ga.

* * *

Francis O. Boylon has succeeded *A. B. Layton* as the official corporate representative of the Crown Zellerbach Corp., San Francisco, Calif., in TAPPI.

T. C. Warren has succeeded *G. Meerberger* as the official corporate representative of the International Paper Co., New York, N. Y., in the Technical Association.

Pietro Molla has succeeded *Aldo Corvaja* as the official corporate representative of Cartiera Saffa, Milan, Italy, in TAPPI.

* * *

J. E. Goetz has succeeded *P. F. Holstein* as the official representative of Westinghouse Electric Corp., E. Pittsburgh, Pa., in TAPPI.

T. A. Fearnside has succeeded *Fred W. Argue* as the official representative of Stone & Webster Engineering Co., Boston, Mass., in the Technical Association.

F. G. Stuller has succeeded *J. W. Snavely* as the official representative of Chain Belt Co., Milwaukee, Wis., in TAPPI.

INDUSTRY NOTES

North American

Statistics

*Pulp, Paper, and Board: Summary for 1959**

Paper and board production in the United States during 1959, amounting to 34,051 thousand tons, was 11% above the level of both 1958 and 1957. Similarly, wood pulp production, at 24,257 thousand tons, was 11% greater than in 1958. Comparable production figures for 1958 for paper and board and for wood pulp were 30,811 and 21,796 thousand tons, respectively.

Paper production totaled 14,923 thousand tons compared to the 1958 output of 13,525 thousand tons. Paperboard production in 1959 amounted to 15,704 thousand tons, as compared to 14,133 thousand tons in 1958. With the exception of special paperboard stock and construction paper, production of all other major grades of paper and paperboard increased in 1959 over 1958, ranging from 16% for special industrial paper to 7% for sanitary tissue stock.

Wood pulp production also showed an increase of 11% over 1958, the range being from 18% for semichemicals to 7% for unbleached sulfate.

The consumption of wood pulp, including that consumed for other than paper and board manufacturing, was 25,157 thousand tons and consumption of fibrous materials other than wood pulp amounted to 10,210 thousand tons. Pulpwood consumption amounted to 38,943 thousand cords, roughwood basis.

These preliminary 1959 figures are the result of a summation of the monthly reports on Form M26A, "Pulp, Paper, and Board (Monthly Report)" and Form M26E, "Monthly Report of Consumers of Wood Pulp (Other than Paper and Board Manufacturers)." The statistics represent practically complete coverage of the operations of all known wood pulp, paper, and board mills in the United States, including Alaska. Final and more detailed figures for 1959 will be published in a summary report at a later date.

Overseas

Russia

Soviet Patent Practice

Relatively little is known in the West of Soviet patent law and practice. Besides language difficulties, perhaps the main reason for our ignorance is that the U.S.S.R. has never belonged to the International Convention for the Protection of Industrial Property. Since its establishment in 1883, the International Convention has drawn into its membership all the leading industrial nations except Russia and China. The principal industrial countries in the Soviet block, Bulgaria, Czechoslovakia, Hungary, Poland, and Rumania have remained in the Convention and still adhere to it. East Germany too purports to belong to the convention though she is not recognized in the West as having sovereign status.

Although it does not provide for international patents, the Convention does bind each member country to give legal protection to the nationals of other member countries on terms equal to those offered to its own nationals. The Convention also enables an applicant for a patent in one member country to wait for one year before applying for a patent for the same invention in another member country. According to the Soviet Invention Law, promulgated on May 1, 1959, foreigners are given rights equal with Soviet citizens on the basis of reciprocity.

The Soviet idea of a patent is similar to that of the West. Under Soviet law, an inventor may exploit his invention for 15 years after which anyone is free to use it. Although patents are still granted in the U.S.S.R., since 1931 an alternative much more congenial to the Soviet economic system has been available to the Soviet inventor. In that year, alongside the existing patent system the certificate of authorship was introduced. The Soviet inventor is still free to choose between a certificate or a patent, but he is given every encouragement to apply for a certificate. This document carries with it a substantial financial remuneration, extra vacations with pay, a favorable mark in the inventor's labor record, and the procedure costs him less.

Under the 1959 law a certificate holder is entitled to a gold medal and is raised to the dignity of "Meritorious Inventor of the U.S.S.R." This scheme has proved to be very successful; the Soviet Committee for Inventions and Discoveries reviews about 1.5 million applications a year.

Certificates of authorship and Soviet patents are printed in the same form and issued in a single numerical series. But a certificate holder has no control over his invention which is the exclusive property of the state. Despite the tenuous hold an inventor has on his invention, this system has spread to the satellites and to the Chinese Prople's Republic. In East Germany, the industrial patent has been offered as an alternative to the exclusive patent. Such a patent is cheaper to obtain but, since anyone may obtain a license to use the invention, the patent owner has very limited rights.

There are no independent patent agents in the U.S.S.R. and foreign applicants must use the services of the Patent Bureau of the All-Union Chamber of Commerce in Moscow. The equivalent organization to our Patent Office is the Committee for Inventions and Discoveries in the Council of Ministers of the U.S.S.R. This committee is responsible for promoting and directing all inventions and discoveries and a Soviet Citizen may apply for a foreign patent only with its permission.

Before a patent is granted it is very strictly examined for novelty. The Committee for Inventions and Discoveries, which may be assisted by Soviet Technical Ministries, make a thorough search of the technical literature. If the ideas for which a patent is applied have been previously published elsewhere, the application is rejected. Once a patent is granted, the patentee can prevent others from using his invention for manufacturing a product and also prevent the importation of such products.

At the moment China will not allow foreigners to apply for patent protection unless they are resident in the People's Republic.

Switzerland

On January 15, in Zurich, Switzerland, representatives from Austria, Denmark, France, Germany, Great Britain, Holland, Italy, Sweden, and Switzerland founded the European Organization of Manufacturers of Transport Cases in Solid Fibreboard. The purpose of this organization is to represent and safeguard the common interests of the members on an inter-

* *Facts for Industry*, U. S. Dept. of Commerce, Bur. of Census, Series M 26A-09.

national basis. The annual turnover of this industry in Europe far exceeds the sum of one milliard Swiss francs. The office of the organization is with FIDES Union Fiduciaire, 31, Bahnhofstrasse, Zurich.

Paper Manufacturers and Converters

Atlantic Gummed Paper Corp.

Appointment

Jerome J. Kipnees has been appointed vice-president in charge of package engineering at Atlantic Gummed Paper Corp., 1 Main St., Brooklyn, N. Y. Atlantic is one of the country's leading producers of gummed tapes for industrial and commercial sealing, packaging, and shipping; the firm is a pioneer in reinforcing paper with glass fiber.

Mr. Kipnees is well known in the packaging field. He is a member of the Packaging Institute, past chairman of its Corrugated Box Committee, in which he now functions as a member of its Steering Committee and Design, Development and Specifications Subcommittee.

He is a member of the ASTM and serves on its D-6 and D-10 committees; he is also on the Container Testing Committee of TAPPI.

Beloit Iron Works

Appointment

Rudi L. Kutter has been appointed as Beloit's Export Sales Manager.

Rudi Kutter is well known to the world's paper industry through his 30 years' association in the machinery building field. It was pointed out that Mr. Kutter's appointment as Export Sales Manager will bring even closer cooperation between Beloit, its affiliates and licensees throughout the world as well as increased service benefits to Beloit customers.

Bowaters Southern Paper Corp.

June Startup for Catawba Plant

Production of smooth-on-both-sides hardboard at the new $7 million plant of Bowater Board Co, Catawba, S. C., is scheduled to get under way early in June.

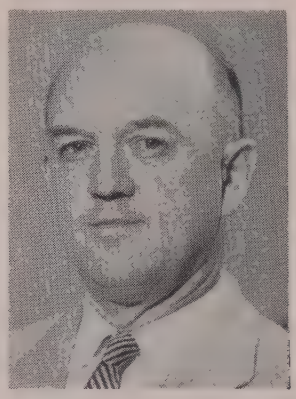
The plant has been designed to produce 160 million sq. ft. of hardboard a year.

Brown Co.

Appointment

Promotion of Karl M. Guest of Gorham, N. H., to the new position of manager, kraft pulp and paper manufacturing at Brown Co. has been announced by Edward H. Petrick, vice-president and general manager-paper division, of the northern New England pulp, paper, and forest products firm.

R. L. Kutter, Beloit Iron Works



Karl M. Guest, Brown Co.

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Several of the 1,079 testers available from TMI
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COMPRESSION-TENSION FLEXURE-SHEAR
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1 INSTRUMENT *for Testing* smoothness
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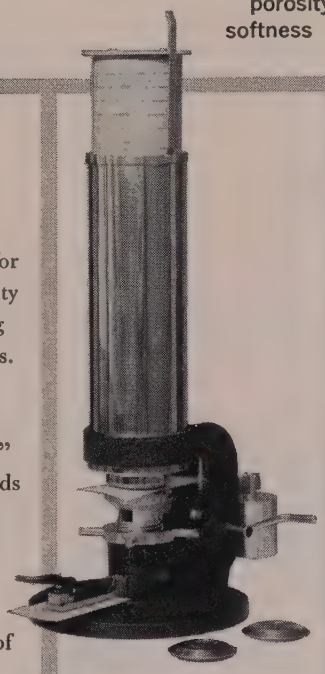


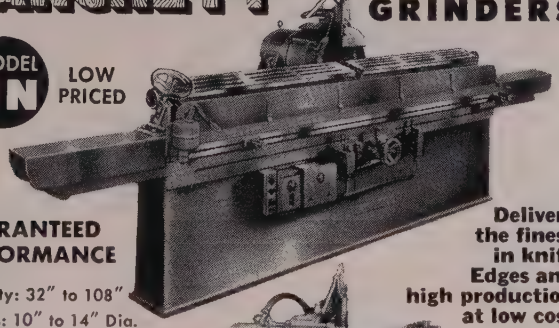
Simply interchanging the lower test plates of the Gurley-Hill S-P-S Tester converts this instrument for testing smoothness, porosity or softness of any printing and most industrial papers. Meets TAPPI and ASTM "Suggested Method for Determining Smoothness," as well as standard methods for finding air resistance or porosity.

Write for Bulletin 1400, describing complete line of Gurley paper testers.

W. & L. E. Gurley, *Station Plaza and Fulton Streets, Troy, N. Y.*

HANCHETT KNIFE GRINDERS

MODEL DN LOW PRICED



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Capacity: 32" to 108"
Wheels: 10" to 14" Dia.
Table Drive — Timing Belt with Elec. Reversing Motor
Motor — 3 H.P.

Delivers the finest in knife Edges and high production at low cost

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MODEL GK HEAVY DUTY

Capacity: 32" to 196"
Wheels: 14"—16"—20" Dia.
Motors: 3 to 15 Horsepower
Table Drives: Mechanical—Electric—Hydraulic
Precision Built—accurate—rugged and quiet

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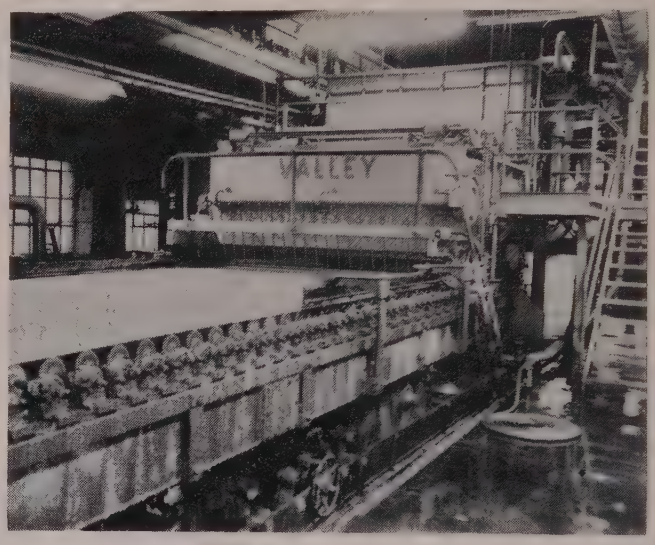
Mr. Guest will be responsible for all operations of Brown's kraft pulp mill and bleachery and would exercise general supervision over the cascade paper mill in nearby Gorham and Riverside paper mill in Berlin, both of which are supplied with pulp from the kraft mill via pipelines. He will report directly to Mr. Petrick.

Chase Bag Co.

New Headbox on Fourdrinier

As part of an expansion and improvement program, Chase has installed a new headbox on the fourdrinier paper machine at their Chagrin Falls, Ohio, paper mill. The headbox was manufactured by Valley Iron Works Co. at a cost of $80,000 before installation. Other new equipment includes an improved automatic rewind reel on one of the larger paper machines. The reel was manufactured by Beloit Iron Works at a cost of $35,000.



The new headbox, Chagrin Falls, Ohio

The headbox was specially designed by Valley Iron Works with refinements in the furnish distribution system to greatly improve uniformity of flow and permit higher speeds. Provisions have been made to include a pressure head on the headbox to increase even more the speed and efficiency of operation.

The Chase Paper Mill specializes in the manufacture of papers used in many industrial markets. Among these, kraft for spinning and twisting paper yarn is important. Paper for steel interleaving, for steel wrap and in food processing are others in Chase's broad industrial line. Chase specializes in custom requirements and maintains an engineering staff to help customers develop special papers for specific end uses.

Crossett Co.

Bleached Leatherneck Papers

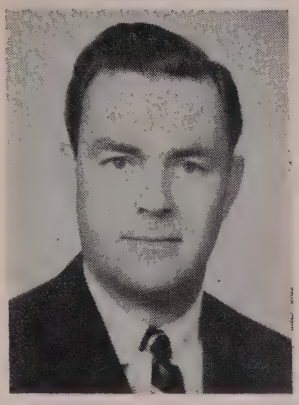
Crossett Paper Mills is now producing full bleached Leatherneck kraft papers.

Crossett Paper Mills is now stocking standard sizes of bleached Leatherneck Butchers for merchant customers, and is offering full bleached wrapping paper in machine trim runs. The new full bleached Leatherneck converting papers are offered in a variety of grades, including garment bag, variety bag, and standard converting.

Bleached Food Board Coating

Crossett Paper Mills has announced that it will install equipment for the application of clay and other types of coating to bleached food board.

R. E. Flowerree, Jr., Georgia-Pacific Paper Corp.



Albert G. Naudain, Georgia-Pacific Paper Corp.

Installation of the machinery at a cost of $1,500,000, will probably begin in the spring and be completed by the middle of the year.

Crown Zellerbach Corp.

Appointments

William E. Parkinson, resident manager of C.Z.'s Carthage paper mill, has been appointed assistant manager of the St. Francisville Paper Co. mill in Louisiana.

Succeeding Mr. Parkinson as Carthage resident manager is Thomas I. Meehan, who has been assistant resident manager of the mill since January, 1955.

General Box Co.

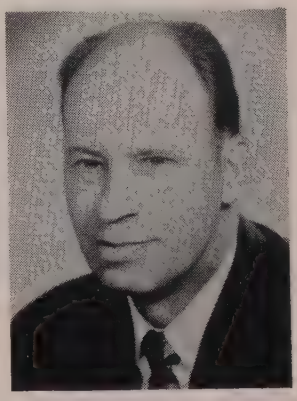
Corrugated Sheet Plant for Meridian

A corrugated sheet plant is to be added to the company's present facilities at Meridian, Miss. Operations are expected to begin in the fully equipped plant on approximately April 15, 1960. The plant will be under the overall management of Mr. C. E. Keene, general manager of the company's Meridian operation.

Georgia-Pacific Corp.

Juneau Pulp Mill

Georgia-Pacific Alaska Co. has made substantial expenditures in connection with the proposed Juneau Unit pulp mill enterprise. A mill site of approximately 75 acres of Douglas Island has been purchased and a complete 500-ton per-day mill has been designed. Water surveys, including water supply and effluent disposal, have been completed; plans for logging the $7\frac{1}{2}$ billion board foot timber unit have been under way for some time, and market and power surveys are under way.



William J. Shelton

Appointments

R. E. Flowerree, Jr., will become president and chief executive officer of Georgia-Pacific Paper Co., wholly-owned subsidiary of Georgia-Pacific Corp., on April 1. H. Stuart Daniels, now president of the paper subsidiary, will assume the new post of chairman of the board of Georgia-Pacific Paper Co. on the same date.

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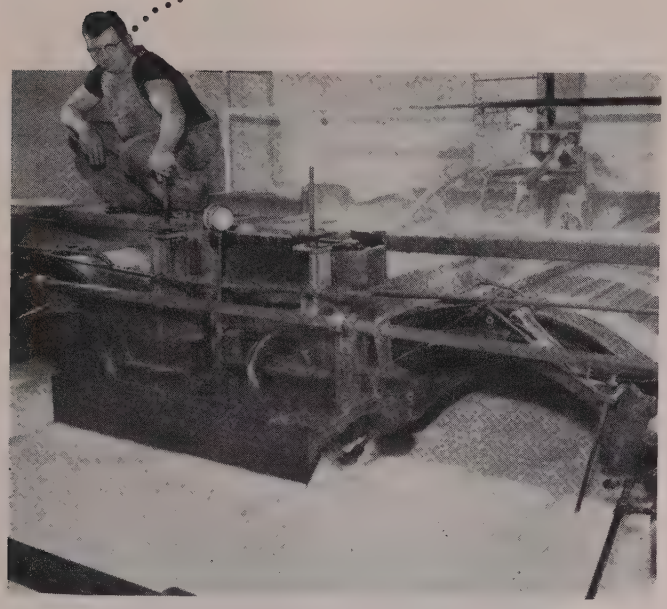
To maintain uniform paper quality ... we add SILICA SOL at the Bird Screen



This mill has used silica sol (made from N sodium silicate) for fifteen years to retain fines and clay on the wire. Here are the benefits which they obtain.

1. **A uniformly smooth and "closed" sheet: thus, producing a better printing surface.**
2. **More fines and clay retained on the wire, which reduces solid contents of white water.**

The application of silica sol is completely automatic and provides continuous even flow of material to the paper machines.

These quality and economy advantages of sodium silicate can be obtained in your operations. It will pay you to know more about head-box additions.

Send for free bulletin #6-1.

PHILADELPHIA QUARTZ CO.
1141 Public Ledger Bldg., Philadelphia 6, Pa.

PQ SOLUBLE SILICATES

Associates: *Philadelphia Quartz Co. of Calif. Berkeley & Los Angeles, Calif.; Tacoma, Wash.; National Silicates Limited, Toronto & Valleyfield, Canada.*

Trademarks Reg. U.S. Pat. Off.

PQ PLANTS: ANDERSON, IND.; BALTIMORE, MD.; BUFFALO, N.Y.; CHESTER, PA.; JEFFERSONVILLE, IND.; KANSAS CITY, KANS.; RAHWAY, N.J.; ST. LOUIS, MO.; UTICA, ILL.

John C. Redd, The Mead Corp.

Henry G. Caldwell, The Mead Corp.

Full responsibility for sales of the paper company will be assumed by Albert G. Naudain, vice-president of the paper subsidiary who has been serving as assistant to H. Stuart Daniels in charge of sales.

The Mead Corp.

Appointments

Organizational changes made at the Mead Research Center, Chillicothe, Ohio, have resulted in the promotion of three men to positions of greater responsibility.

John C. Redd has been named director, research and development; Henry G. Caldwell has been appointed director of corporate technical service; and Charles H. Schneider is the new research administrator.

Ellsworth H. Shriver has been named assistant director of product planning.

Charles W. Schneiderhan has been named assistant director of market research for The Mead Corp.

Mosinee Paper Mills Co.

Appointments

Mosinee Paper Mills has created three new positions on its sales staff and has promoted three men from within the organization to fill them.

Donald E. Allen is now manager of market development, and F. P. Stone has been elevated to one of the new district manager positions.

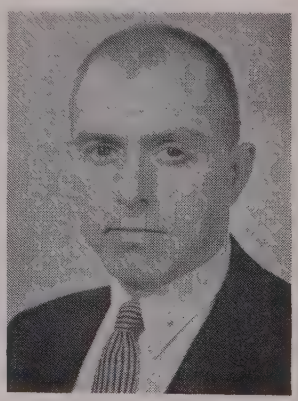
Edward J. Rolain has been promoted to district manager of the Chicago office.

Nekoosa-Edwards Paper Co.

Foundation Scholarships for 1960

Nekoosa-Edwards Foundation has announced it will again award up to four scholarships to qualified students this

Charles H. Schneider, The Mead Corp.



Ellsworth H. Shriver, The Mead Corp.

Ralph C. Kinzel, Watervliet Paper Co.

Paul T. Hoelderle, Watervliet Paper Co.

year, making a total of 32 awards since introduction of the program in 1953. The Foundation was established in 1947 by Nekoosa-Edwards Paper Co., a leading producer of business papers.

Each award is $500 for an academic year. Awards may be renewed yearly for a maximum of 3 additional years, thus the awards are worth up to $2000 each. In addition, each Wisconsin college or university selected by a scholarship winner will receive an annual cost-of-education grant equivalent to the tuition but not to exceed $500 per year.

One Million Man-Hours Safety Record

One million man-hours of operation without a lost-time accident was established by the Nekoosa, Wis., mill of Nekoosa-Edwards Paper Co. on March 2.

Approximately 780 employees participated in establishing the safety mark. Previous safety records were established in 1957 when the Nekoosa mill scored 1,332,000 accident-free work hours and the Port Edwards mill passed the 2,000,000-hour mark.

Rhinelander Paper Co.

New Bleach Plant

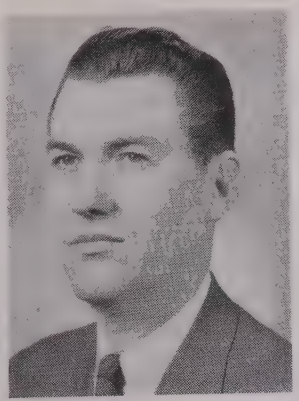
A continuous bleach plant with a maximum capacity of 120 tons of bleached stock per day will be built this summer at the Rhinelander Paper Co., Division of St. Regis Paper Co. The new bleach plant will be erected on the site of the old bleach liquor plant at Rhinelander, Wis.

Target date for completion is early September.

Watervliet Paper Co.

Appointments

Ralph C. Kinzel formerly with Rhinelander Paper Co., is now chemist in research and development work, and Paul T. Hoelderle, recent graduate of Western Michigan University's Pulp and Paper School, is also chemist in research and development work at the Watervliet Division of Hammermill Paper Co.



John E. Watson

Wrenn Paper Co.

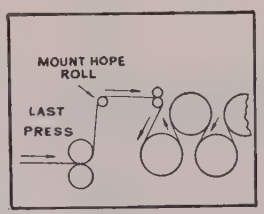
Appointments

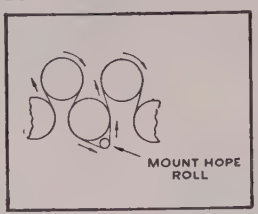
John E. Watson, research engineer, has been named technical director at Wrenn Paper Co., Middletown, Ohio. In his new assignment, he will be responsible for the technical functions and research facilities at The Mead Corp. subsidiary.

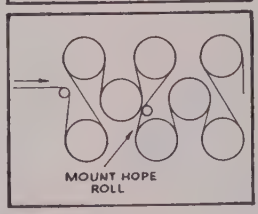
by STRETCHING-the-SHEET with

MOUNT HOPE ROLLS

3 TYPICAL INSTALLATIONS







Yes, many mills are actually increasing sheet width in the drying sections by 1 inch or more, through the use of MOUNT HOPE VARI-BOW ROLLS! These highly versatile bow-shaped rolls are installed wherever their positive, automatic stretching action is needed most. They can then be quickly and easily adjusted to varying stock consistencies and web requirements. Get full details on this simple, positive way to stretch the sheet . . . the practical way to improve your operating economy. A MOUNT HOPE Engineer will "show you how". Simply fill out and mail coupon below.

MAIL COUPON TODAY!

MOUNT HOPE MACHINERY COMPANY

MOUNT HOPE MACHINERY COMPANY
62 Fifth Street Taunton, Mass.
Plants at Taunton, Mass. and Charlotte, N.C.

Please have a MOUNT HOPE Engineer call at my mill and show me how MOUNT HOPE ROLLS can improve my operations.

NAME _____

TITLE _____

FIRM _____

ADDRESS _____

CITY _____ ZONE ____ STATE _____

Educational Institutions

The Institute of Paper Chemistry

Grant from National Science Foundation

The National Science Foundation has announced the awarding of a grant of $8,050 to The Institute of Paper Chemistry in support of a summer program for college teachers.

This eight-week program is one of 57 research participation programs for about 550 teachers of science and mathematics approved by the National Science Foundation for summer grants totaling nearly one million dollars. Approximately 400 of the teachers will come from secondary schools, and the remaining 150 will come from junior colleges and small colleges without appropriate research facilities.

Fifth Industry Seminar

The Fifth Industry Seminar, conducted by The Institute of Paper Chemistry in Appleton, Wis., will begin on June 15 and will continue through July 7, 1960. This is the fifth in an annual series of summer programs designed to give men in the pulp and paper industry an increased awareness of the contributions to be made by science and technology to the industry.

Presentations by Institute staff members will provide the core of the Seminar. Among the subjects considered will be wood as a raw material, cambial chemistry, wood structure, wood components, lignin chemistry, and their relationship to the utilization of wood.

Problems in pulping, bleaching, and papermaking will be buttressed by consideration of biological problems, fiber behavior and beater adhesives, stock preparation, drainage, formation, and drying.

Important aspects of converting problems including the mechanical properties of paper, coating, packaging, and graphic arts will be covered.

The seminar, an activity of the continuing education program at The Institute of Paper Chemistry, will be under the direction of Dr. A. Neil McLeod, Institute Economist.

Lehigh University

Lehigh University has received a grant of $39,300 from the National Science Foundation for the support of basic research entitled "Wetting of Solids by Liquids," to be conducted during the next three years.

Dr. Albert C. Zettlemoyer, professor of chemistry, will direct the project. He will be assisted by Dr. John J. Chessick, research assistant professor of chemistry, and a graduate fellow to be appointed in the future.

University of Michigan

Funds to continue and expand research on Lower Michigan's top timber-producing tree—the aspen—were granted to the University of Michigan on February 18 by the Lower Michigan Pulpwood Research Association (LMPRA).

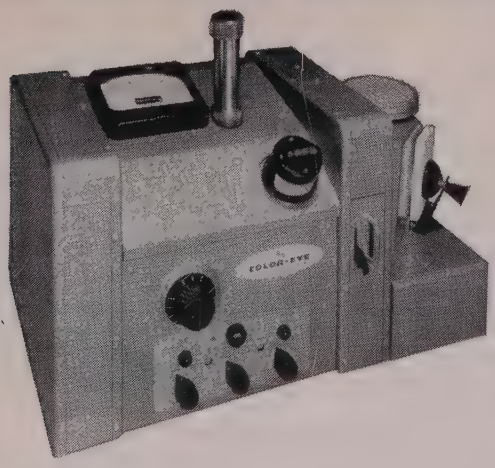
The first research project financed by the group was a study of the re-establishment of aspen ("popple") on lands where the valuable timber tree had failed to reproduce itself naturally. This study by the U-M School of Natural Resources is still in progress.

The studies will be made by faculty members of the U-M Departments of Forestry and Wood Technology and their graduate students, utilizing the various University facilities, including the forest lands of the Biological Station, the Botanical Gardens, Wood Utilization Laboratory, and specialized equipment.

Illinois Institute of Technology

The 1960 Computer Applications Symposium sponsored by Armour Research Foundation of Illinois Institute of Tech-

Color Control with COLOR-EYE®



This unique combination of a colorimeter and abridged spectrophotometer measures color differences directly or against a permanent reference standard. For use in production or laboratory, Color-Eye is completely portable, rugged and stable.

FOR THE PAPER INDUSTRY . . .

COLOR-EYE makes possible simple and rapid determination of "beater room" dye and colorant additions. Color-Eye also provides numerical values for control of pulp brightness, fillers and pigments.

For complete information write for brochure "Color-Eye" Model D.

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Specialists in Photometric Analysis
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Subsidiary of ROYAL McBEE CORPORATION

nology will be held October 26 and 27 at the Morrison Hotel, Chicago.

The conference will stress user experience on the frontiers of computer applications and programming techniques. Invited papers will represent business and management, and engineering and scientific applications.

Inquiries concerning the conference should be addressed to Andrew Ungar, conference program chairman, Armour Research Foundation, 10 W. 35th St., Chicago 16, Ill.

University of Maine

Dr. Roy P. Whitney, dean and vice-president of The Institute of Paper Chemistry, Appleton, Wis., will be a member of the staff for the first Summer Institute for the Pulp and Paper Industry at the University of Maine, July 11–August 19.

Resident faculty of the State University, faculty members from other institutions, and leaders in the industry will conduct courses in two three-week sessions. From July 11–29 the Institute will be concerned with pulp technology, and from August 1–19 with paper technology.

Lowell Technological Institute

Two-Week Summer Course

The department of Paper Technology at Lowell Technological Institute this year again will present a two-week summer course in "Paper—Its Properties and Uses" with the endorsement of the Boston Paper Trade Association and the New England Paper Merchants association. It will be given June 6 to 17 at LTI by Professors Norwood H. Keeney, Edward M. Engel, and Charles J. Higgins of the paper technology faculty.

Topics to be covered in the course include an introduction to pulp manufacture, an introduction to paper manufacture, mill visits for papermaking and paperboard-making, paper converting theory, classification and uses of paper and board, handsheet making and testing, papermaking arithmetic and economics, theory and laboratory in beater additives, printing inks and printing processes with printing plant visits, paper converting laboratory, kraft papers, cartons and containers with kraft paper mill and bag plant visits and a converting plant visit, and paper problems from the sales approach. A graduation banquet will take place at the conclusion of the course.

Enrollment for the course is limited, and applications must be sent before May 10 to Paper Summer Course, Lowell Technological Institute, Lowell, Mass., with a deposit of $10 which will be returned if the application cannot be accepted. Fee for the course including tuition, room, meals, books, and transportation on field trips is $225. For commuters the fee is $150.

Industry Suppliers

Allis-Chalmers Manufacturing Co.

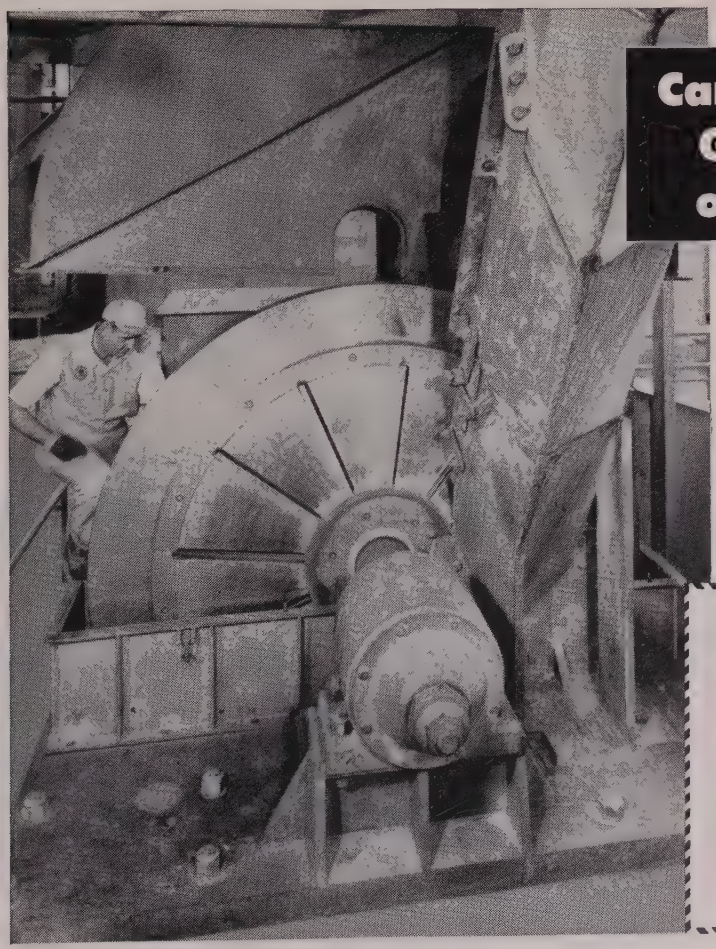
Engine Plant at Harvey, Ill.

Plans for construction of a multimillion dollar engine manufacturing plant at the Harvey, Ill., works of Allis-Chalmers have been announced

The new plant, with about 515,000 sq. ft. of floor area will occupy part of 35 acres of land acquired by the company in 1957. Construction is scheduled to start immediately near the site of a recently completed engineering development and research laboratory.

Industrial Equipment Division Formed

Allis-Chalmers has combined its Industrial and General Products Divisions into a new operating unit called the



Carthage-Norman Chippers Give You Greater Yield of Higher Strength Pulp

With its unique helicoidal disc segments and variable-bevel knives, the Carthage-Norman Chipper produces the highest percentage of "to size" chips. There are fewer compressed or bruised chips and ½% to 1% less sawdust — a feature which can pay for the chipper in one year. Knives wear longer — cost less. Heavy-duty construction results in exceptionally low maintenance costs.

CARTHAGE MACHINE CO.
CARTHAGE, N. Y.

E. L. Crowley
3224 N. Fulton Ave.
Hapeville, Ga.
POplar 6-9858

Hyman Supply Co.
Wilmington, N. C.
ROger 2-5294

Machine Products Co.
1625 Forrest Ave.
Gadsden, Ala.
LIberty 7-1121

Ray Smythe Co.
511 Park Bldg.
Portland, Ore.
CApitol 3-0502

The Chesapeake Supply & Equipment Co.
Forest and Railroad Ave.
Dover, Del. REdfield 4-5991

Industrial Equipment Division, with W. M. Wallace as vice-president and general manager of the new division. G. A. Saar was appointed assistant general manager.

The new division includes the compressor, processing machinery, centrifugal pump, control, and the industrial systems departments, plus the Norwood Works, motor and pump manufacturing facility.

Canadian Allis-Chalmers, formerly a part of the Industrial Equipment Division, will now operate as a separate division of the Industries Group. H. M. Schudt, president of Canadian Allis-Chalmers is divisional general manager.

Ampco Metal, Inc.

Nonsparking Safety Tools

Nonsparking safety tools are described in a catalog recently revised and brought up-to-date by the manufacturer, Ampco Metal, Inc.

Ampco safety tools have been tested by the Factory Mutuals Laboratories and approved for use where a hot spark could mean fire or explosion. A report, recently issued by the U. S. Department of Commerce, and entitled "Research and Development Report on Sparking Characteristics of Metals," concludes that hand tools of Ampco Metal (aluminum bronze) and Ampco Beryllium Copper are safe to use in explosive atmospheres of gasoline vapor . . . see report PB-151650. In addition to their nonsparking qualities, Ampco tools are noncorrosive and nonmagnetic.

Copies of the Ampco Safety Tool catalog may be obtained from: Ampco Metal, Inc., Box 2004, Milwaukee 1, Wis.

Armour Alliance Industries

New Industrial Adhesives Plant

Armour Alliance Industries, Alliance, Ohio, announces the opening of a newly constructed industrial adhesives plant located at Philadelphia, Pa. Covering over 15,000 sq. ft. of floor area, the new plant, equipped to formulate animal-base, resin-base, vegetable-base, and blood adhesives, will service industrial adhesive customers throughout the eastern United States.

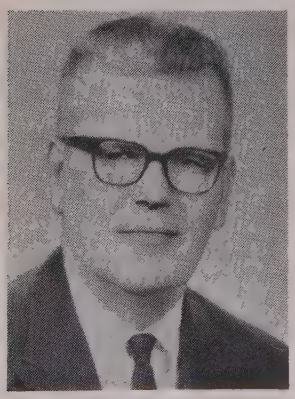
Bailey Meter Co.

Appointments

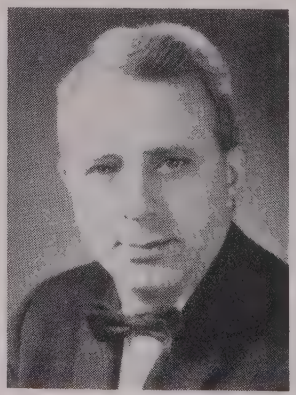
S. G. Dukelow, manager of the New Orleans district, has taken over managership of the San Francisco district. He succeeds V. A. Rumble who has retired after 37 years with the company—30 of them as San Francisco manager. W. P. Davenport, an industry specialist in the Pulp & Paper Division, East Orange office, has been named manager of the New Orleans district.

Dukelow joined the company as an engineering trainee in 1941. He was named manager of the New Orleans district in 1947, after having gained experience as a sales-service engineer in the Chicago, Denver, and Houston district offices. A graduate of Kansas State College, Dukelow holds a B.S. degree in mechanical engineering.

Davenport joined the company in 1937 as an engineering trainee. He worked in the Philadelphia and New York district offices prior to being assigned to the East Orange office (part of the New York district). Davenport is a 1937 graduate of Penn State and holds a B.S. degree in mechanical engineering.



S. G. Dukelow

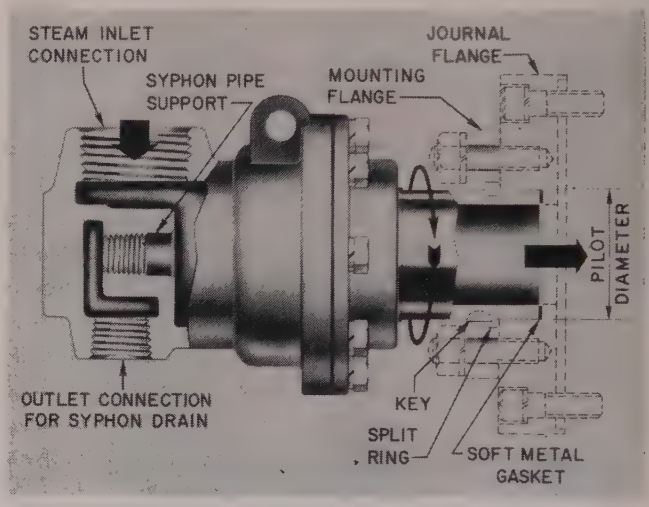


W. P. Davenport

Barco Mfg. Co.

Precision Type Flanged Rotary Joints

Improved convenience in installation and accurate control of concentricity are important features of new Type CF rotary joints developed by Barco Manufacturing Co., of Barrington, Ill. The design eliminates need for threaded connection of the rotary sleeve, which is sometimes difficult to disconnect from rotating drum journals after lengthy service, particularly in the case of large size joints.



Sectional view of Type CF rotary joint

The new Type CF flanged joints are now available in 2, $2^1/_2$, and 3 in. sizes suitable for up to 200 p.s.i. saturated steam or 400 p.s.i. cold working pressure. Also, hot oil, under 100 p.s.i., can be handled up to 500°F. All sizes are built so that they can be used for either single-flow or syphon-flow service.

Detailed information on Barco Type CF rotary joints is contained in Catalog Sheet 331. Copies may be obtained by addressing requests to Barco Manufacturing Co., Dept. J. 31, 500 Hough St., Barrington, Ill.

Bauer Bros. Co.

Digesters Booklet

A 12-page, well illustrated booklet describing Bauer digesters and related equipment to meet all pulp cooking requirements is now available from The Bauer Bros. Co., Springfield, Ohio.

Three digesters—the Rapid Cycle batch cooker, and two continuous digesters, the M & D model and the Grenco model—are explained in detail. Information is also included on the Bauer-Grenco rotary valve for continuous digesters and automatic controls.

Ask for Bulletin P-30.

The Borden Chemical Co.

Ink and Lacquer Dept.

James A. Wold has been named general manager of the newly acquired Commercial Ink and Lacquer Co. operations of Borden. He was formerly general manager of the com-

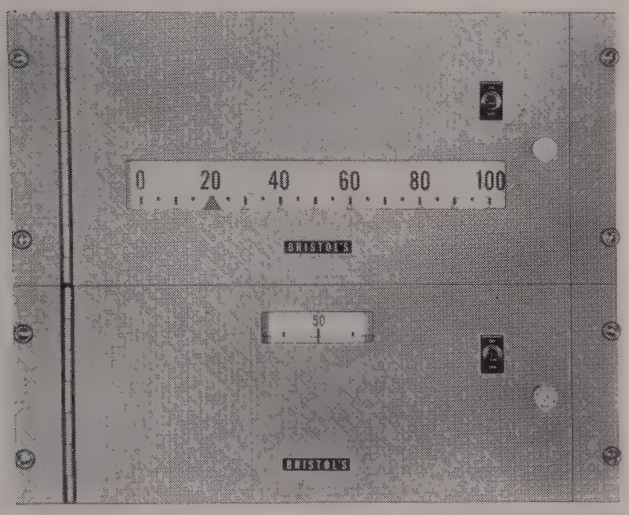
pany's Consumer Products and Resinite departments. The new ink operation will formally be known as the Ink and Lacquer Department of the Borden Chemical Co.

The Ink and Lacquer Department, Fair Lawn, N. J., manufactures gravure and flexographic inks, varnishes and lacquers for use by the packaging, gypsum board, printing, and laminating industries.

The Bristol Co.

Rack-Mounting Servomechanisms

Two new rack-mounting Dynamaster servomechanisms are being offered by Bristol. The new models are mounted in hinged swinging panels to fit standard 19-in. RETMA relay racks. Both models are suitable for applications in comput-



Rack-mounting Dynamaster servomechanism

ing and all types of control systems, indicating gage applications, etc.

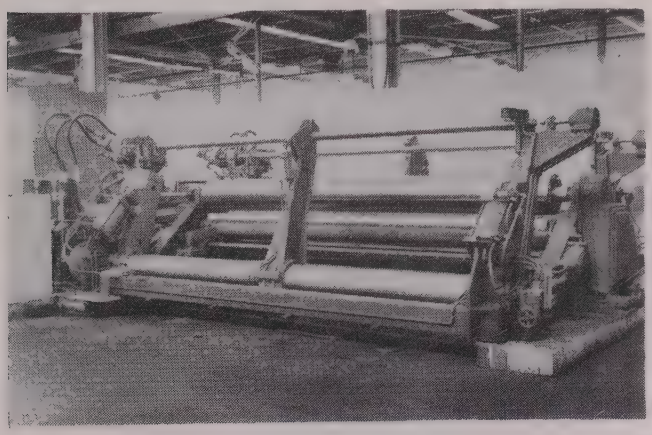
Both servomechanisms use the same basic amplifier used in Bristol's Series 663 Dynamaster, null-balance potentiometer instruments. Measuring and power circuits are similar to those of standard Dynamaster instruments. The bridge supply utilizes either a Zener reference source or a mercury cell (no standardizing).

Complete information may be had from The Bristol Co., Waterbury 20, Conn.

Cameron Machine Co.

World's Largest Duplex Winder

Cameron Machine Company, Dover, N. J., has built a 147 in. trim width duplex winder. This machine is believed to be the world's largest winder of this type.



The 147-in. Duplex winder

FABRI-VALVE

SOLVING *your* valve problems is our business.

If you are faced with difficulties in metering, corrosion, tight shutoff, or handling suspended solids, Fabri-Valve has the answer.

Valve shown above is a cylinder operated, 12-inch, bonnetless stock valve, modified to include a Vee Grip type inspection port. Valves of this type are ideal for handling high density pulp stock.

We can assure you fast action and satisfaction.

Write, wire, or call for more information.

WEDGE GATES
STOCK VALVES
BUTTERFLY VALVES
CHECK VALVES
DIGESTER VALVES
V-PORT METERING

TRADE MARK
FABRI-VALVE
COMPANY OF AMERICA
2100 N. Albina Avenue
P.O. Box 4352 Portland 8, Oregon

The new winder, furnished to Nicolet Paper Co., West DePere, Wis., will be used in conjunction with a supercalender producing glassine. It has a 50 in. diameter rewind capacity and is capable of running at 2000 f.p.m. A hydraulic main drive and individual hydraulic drives to both rewind shafts are employed.

Centrifix Corp.

Move to Houston, Tex.

After March 31st, Centrifix Corp.'s general offices, engineering, and administration headquarters will be located at 1017 LeHall St., Houston, Tex. A Cleveland office with Herbert R. Hayes as manager will be located at 2032 West 105th St., Cleveland, Ohio.

CompuDyne Corp.

Jarco Services Acquired

The CompuDyne Corp. of Hatboro, Pa., manufacturers of computer-operated automatic control systems and components has announced the acquisition of Jarco Services, Inc., Tulsa, Okla. Jarco produces electronic capacitance-type level probes for the missile, petroleum, pipeline, chemical, and bulk-materials industries.

Jarco will be operated as a wholly owned subsidiary.

Dow Chemical Co.

Paper-Coating Latex

Dow Latex 630, a new latex for pigmented paper and paperboard coatings, is a type of styrene/butadiene latex markedly different from previous copolymers.

The high shear stability of Dow Latex 630 promises maximum utility on all types of commercial coating equipment. In addition, the improved starch compatibility of the latex eliminates the need for protective colloid. Improvement of wet pick resistance and indications of body stock strengthening, coupled with excellent dry pick resistance, suggest wide utility for all types of printed papers.

C. W. Cairns, Product Sales Manager, said the latex used in paper and paperboard coatings imparts the highest degree of printability.

The price of Dow Latex 630 is 31 cents a pound for latex solids, in tank car quantities (slightly higher west of the Rockies).

$30 Million for Louisiana Division

A $30 million expansion program at The Dow's Louisiana Division, Plaquemine, La., was announced today by Leland I. Doan, Dow president.

The expansion, which will take 2 years, will include a plant for the production of ammonia, increases in production capacity for chlorine, caustic soda and vinyl chloride, and additions to power and steam generating facilities.

Fibrous Glass Products, Inc.

*FIT*rite in Four Thicknesses*

FIT*rite, the molded fiberglass insulation for standard pipe fittings, is now available in four thicknesses, $^1/_2$, 1, $1^1/_2$, and 2 in. and comes in standard sizes for welded and cast ells, tees, and upon request, for special shapes.

Free literature on FIT*rite molded fiberglass pipe-fitting insulation is available from Fibrous Glass Products, Inc., Alpa Plaza, Hicksville, L. I., N. Y.

Food Machinery and Chemical Corp.

FMC Drops Westvaco Name

Effective April 1st, Food Machinery and Chemical Corp. will drop the name Westvaco from its Divisional and brand identifications. The former Westvaco Divisions will in future be known as the Chlor-Alkali and Mineral Products Division of the Corp.

Fit-Rite pipe-fitting insulation by Fibrous Glass Products, Inc.

General Aniline & Film Corp.

New West Coast Branch

General Aniline has announced it will build a new west coast branch sales office and distribution center in South San Francisco.

The new facility, which will have 45,000 sq. ft. of floor space, will be a consolidated sales office and warehouse for the corporation's three main divisions—Ansco, Ozalid, and Dyestuff & Chemical—to serve western and northwestern states.

General Electric Co.

Silicon Rectifier Conversion Units

GEA-7060, four-page bulletin, describes G.E.'s new oil-filled silicon rectifier conversion units for electrostatic precipitator and other types of high-voltage power supplies.

Illustrated publication gives detailed information on product features, applications, cost savings, and reduced maintenance. It includes photographs, line and dimensional drawings, cost savings chart, ratings, application and price tables.—General Electric Co., Schenectady 5, N. Y.

Glenfield & Kennedy, Inc.

Microstraining

A four-page bulletin which graphically illustrates three microstraining installations is available from Glenfield & Kennedy, Inc., 275 Halstead Ave., Harrison, N.Y.

This system of automatic filtration is widely used for the clarification of raw water supplies such as lake water and river water.

Hercules Powder Co.

Financial Aid to Education

Over $110,000 in unrestricted grants-in-aid is being distributed by Hercules among 30 colleges and universities. The unrestricted grants-in-aid program gives complete freedom in the use of these funds to the heads of departments of chemistry, chemical engineering, physics, mechanical engineering, and others in the participating schools.

Hudson Bay Co.

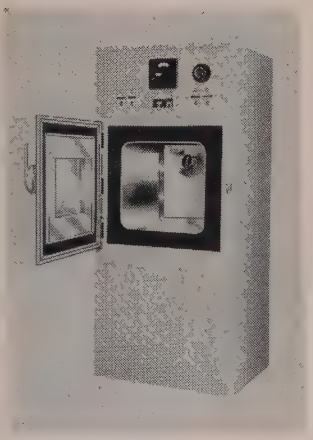
Test Chamber

A new environmental test cabinet with special "add-on" facilities for altitude, vacuum, humidity, and temperature

testing answers the needs of laboratories with expanding environmental test requirements.

Called the Com-pac Cab, it is designed specifically for low temperature operation with an adjustable temperature range from 300°F. to −120°F. Varied testing can be had by merely adding optional equipment. The working chamber is 19 × 19 × 19 in.

Developed by Hudson Bay Co., Division of Labline, Inc., 3070-82 W. Grand Ave., Chicago 22, Ill.



Com-pac Cab test chamber

Jefferson Chemical Co., Inc.

Conroe Plant Manager

Harold R. Horner, Jr., has been appointed Conroe Plant Manager for Jefferson. The new plant acquired from Gulf Oil Corp. on Feb. 1, 1960, will be used for intermediate scale production of new products and for large scale development work on new processes.

The Kordite Co.

Operations Discussed with Japanese

The Kordite Co., Macedon, N. Y., has opened discussions with one of the largest industrial firms in Japan, The Mitsubishi Petrochemical Co., Ltd., Tokyo, for the sale of plastic film products in the Far East.

Preliminary meetings will focus on licensing the Japanese concern to produce and distribute Kordite plastic products in the Far East.

The Lummus Co.

35th Anniversary Luncheon for A. P. Schnyder

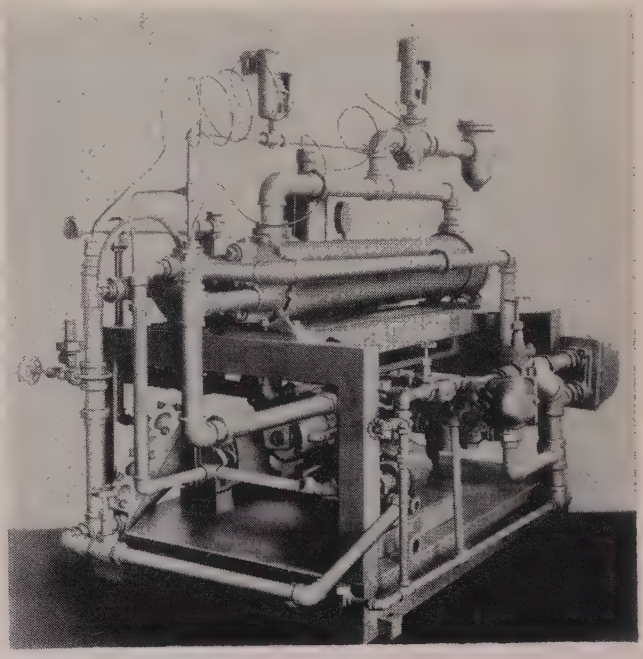
A. P. Schnyder, well-known consultant to the Pulp & Paper Industry, commemorated his 35th anniversary in the industry on February 15 with a luncheon at the Canadian Club in New York for a group of old and new friends, some of whom have known Mr. Schnyder since his initial years in the industry.

Guests at the 35th anniversary luncheon for A. P. Schnyder were, from left to right: H. C. Brown, Director, Chicago Bridge & Iron Co.; F. J. McGovern, The Lummus Co.; C. J. Faulkner, Pur. Agt., Gilman Paper Co. and St. Marys Kraft Corp.; R. E. Grigg, Industry Representative, General Electric Co.; W. W. Cronkhite, Retd., General Electric Co., Mgr. Industry Div.; A. P. Schnyder, The Lummus Co.; R. M. Dickson, Pulp & Paper Mill Engineer, Ebasco Services, Inc.; R. G. Macdonald, Treasurer of TAPPI; D. Breien, The Lummus Co.; W. W. Kraft, The Lummus Co. Standing: W. J. Hemphill (left), Retd., Industry Representative, Johns-Manville Sales Corp.; A. D. Halporn, Consulting Sales Engineer, Combustion Engineering

Milton Roy Co.

Automatic Paste Rosin Size Emulsifier

A new automatic past size emulsifier has been developed jointly by Milton Roy and Monsanto Chemical Co. The packaged system responds automatically to machine demands and when not producing finished size emulsion, it recirculates and reheats size paste. This recirculation feature keeps a supply of paste size to a constant temperature thereby ensuring uniform emulsion consistency.



Automatic paste size emulsifier

For more information, write to Milton Roy Co., 1300 East Mermaid Lane, Philadelphia 18, Pa.

Pump Stroke Length Responds to Flow Rate Changes

Data Sheet D-59-1 explains how controlled volume pumps solved the problem of metering a softening agent into the distribution lines at the two pumping stations serving Ft. Bliss, Tex. By incorporating an automatic stroke length adjustment which responds to changes in flow rates, the manufacturers of the pump ensure a consistent ratio of phosphate to water with varying water pumping rates—automatically and economically.

Monsanto Chemical Co.

Cyanuric Compounds

Monsanto has published a 44-page technical bulletin describing its ACL chlorinated cyanuric acids and salts, a family of dry organic chlorine sources for the compounding of bleaching and sanitizing products.

The bulletin (I-177) describes the physical, chemical, and functional properties of the products, presents performance information and gives suggestions for the proper formulation of the materials into effective solid bleaching and sanitizing agents.

The booklet can be obtained free by writing to Monsanto Chemical Co., Inorganic Chemicals Division, 800 North Lindbergh Blvd., St. Louis 66, Mo.

National Starch and Chemical Corp.

Kofilms Manual

Publication of a 64-page manual on the chemistry and industrial utilization of Kofilm starches was announced by National Starch during the 1960 TAPPI convention.

Kofilms, described in the manual as an important new class of chemical starch derivatives, are made by directly linking acetyl groups to starch molecules. Selective control of this process is said to give Kofilms properties far superior to those of the starches from which they are derived.

Copies from Paper Div., National Starch and Chemical Corp., 750 3rd Ave., New York, N. Y.

Appointment

Leonard J. Wood has been appointed to a new post in which he heads technical and sales-service operations for the Paper Division of National Starch.

Among Mr. Wood's new responsibilities as Paper Division product manager, is the direction of National's broadscale development program for the paper and board industries.

Nichols Engineering and Research Corp.

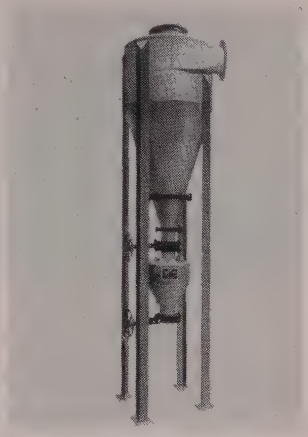
Furnish Precleaner

The Precleaner, a low pressure drop centrifugal cleaner for removing trash from furnish has been introduced by Nichols. The Precleaner may be used ahead of screens or high pressure drop cleaners or in stock preparation systems at pulpers.

Advantages: Large capacity, small space requirements, no moving parts, and low pump head requirements.

Units are furnished in either mild or stainless steel, with manually operated valves or push botton control.

Three sizes available to handle volumes from 1500 to 6000 g.p.m. with a single unit.



The Nichols Precleaner

Olin Mathieson Chemical Corp.

Silicone Coated Multiwall Bag

Development of a multiwall bag with a special silicone coating on the inside for packaging tacky materials has been announced by the Packaging Division of Olin Mathieson.

The coating, originated by Dow Corning Corp., prevents adhesion of the bag to the material being packed. The bag, which has been successfully used as a package for synthetic and natural rubber, can be used for asphalt, candy, adhesives, and similar gummy products.

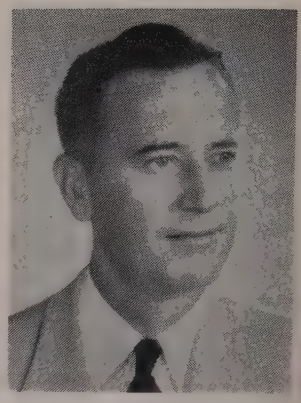
Penn-Olin Chemical Co.

Penn-Olin Chemical Co. is now being formed as a joint subsidiary of Pennsalt Chemicals Corp. and Olin Mathieson Chemical Corp.

The subsidiary, a $6,500,000 venture, has been organized to produce sodium chlorate and other chlorate compounds, and will be owned equally by the two corporations. Preliminary engineering has been completed, and construction is expected to start within 90 days on a 25,000-ton-a-year plant at Calvert City, Ky.

Sodium chlorate, in increasing demand from the pulp and paper industry, is also the major raw material used in the production of ammonium perchlorate, a solid rocket fuel oxidizer, and in the manufacture of defoliants and weed killers.

Vernon Woodside, Olin Mathieson Chemical Corp.



J. L. Pickens, Olin Mathieson Chemical Corp.

Appointments

Vernon Woodside has been named manager of sales development for heavy chemicals in the Chemicals Division of Olin Mathieson, and J. L. Pickens as manager of field sales for heavy chemicals. Both men will be located in Baltimore.

Robert D. Hillmann has been appointed western district sales manager for film operations of the Packaging Division of Olin Mathieson. He will be located in San Francisco.

Onyx Oil & Chemical Co.

50th Anniversary Surfactant Catalog

A 24-page catalog of surface active agents has been published by Onyx.

Each product is described by trade name, active ingredient, per cent activity, physical state, general use, specific applications, and properties.

Copies of this catalog are available from the company, Jersey City 2, N. J.

The Pfaudler Co.

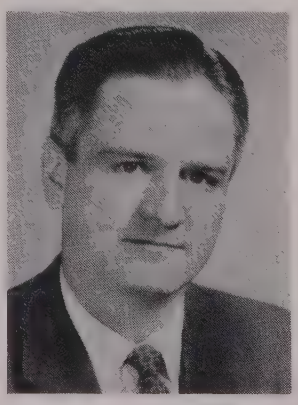
Tantalum Bayonet Heater

A tantalum bayonet heater, believed to be the largest ever produced, has been fabricated by The Pfaudler Co., a division of Pfaudler Permutit, Inc.

The new tantalum bayonet heater has 124 sq. ft. of heater area, and is composed of 52 tantalum tubes, $1^1/_2$ in. o.d. by 72 in. length. It is designed for use in a Pfaudler glassed-steel vessel being used as a nitric acid reboiler.

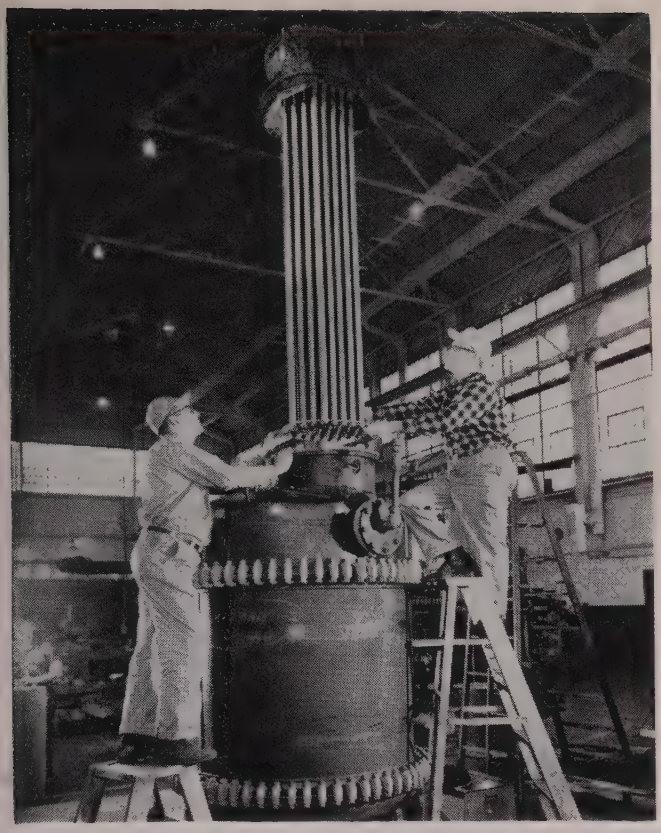
Appointment

John J. Moffett has been appointed as manager, export sales department. The Pfaudler Co., a division of Pfaudler Permutit Inc., is a specialist in Fluidics, a program which com-



Robert D. Hillmann, Olin Mathieson Chemical Corp.

John J. Moffett, The Pfaudler Co.



Pfaudler's tantalum bayonet heater

bines 75 years of knowledge and experience with a wide variety of equipment offerings to solve problems which involve fluids.

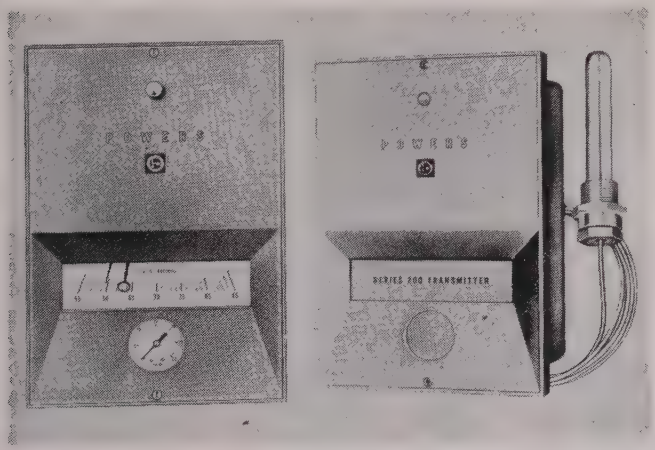
The Powers Regulator Co.

Transmitter-Receiver Controls

Newly designed transmitter and receiver equipment for remote temperature control has been announced by Powers.

Applications of the transmitter-receiver system include both heating-cooling-air conditioning and industrial processes, especially when remote control is involved.

The Series 200 transmitter transduces a temperature measurement into a 3- to 15-p.s.i. air pressure signal from a remote location.



Series 200 receiver-controller, and Series 20 transmitter

Operating in conjunction with the transmitter, the Series 200 receiver-controller maintains a selected temperature at a remote location.

Details are available in Bulletins 371, 371-1, and 371-2 from The Powers Regulator Co., 3434 Oakton St., Skokie, Ill.

Resisto Chemical, Inc.

Release Coating for Fiberous Containers

A plastic release coating for paper and fiber containers has been developed by Dir-Dux Division, Resisto Chemical, Inc. Known as Tar-Dux, the new coating prevents such materials as asphalt, butyl rubber, tar, adhesives, resins, and waxes from adhering to their containers.

Tar-Dux is a water-phase, solvent-free compound, which is milky white in appearance, but forms a transparent film when dry. When applied to paper or paper products, oven-drying at 250°F. for 30 sec. is usually sufficient.

For more information about Tar-Dux, or other related plastic coatings, write: Dri-Dux Division, Resisto Chemical, Inc., P. O. Box 1945, Wilmington 99, Del.

J. O. Ross Engineering

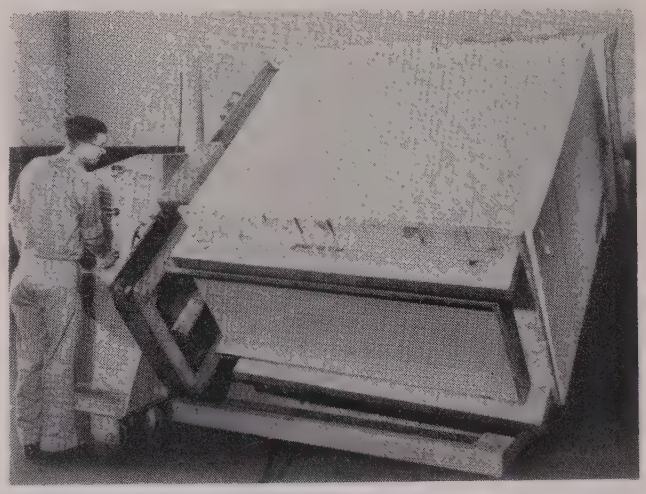
High Velocity Drier Bulletin

A 4-page bulletin gives technical data on three new model high-velocity driers. Air-outlet velocities range from 15,000 to 20,000 f.p.m. with temperatures to 800°F. and beyond in certain applications. Driers may be manually or automatically controlled and are extremely flexible in operation. Ask for Bulletin HV-501, J. O. Ross Engineering, Division of Midland-Ross Corp., 730 Third Ave., New York 17, N. Y.

Southworth Machine Co.

Skid Turner

The fully mobile Southworth skid turner Model ST-5 needs no fixed location, does away completely with foundation pits, steel beams, tracks, etc. It may be moved from location to location and will turn any type skid, handling sizes from 28 × 38 to 52 × 76 in., and accommodating heights from 24 up to 74 in., exclusive of skid.



The ST-5 skid turner

With a capacity of up to 5000 lb., the Southworth Skid Turner is ready to operate as soon as delivered. When not turning skids, it is designed to serve as a lift table as well.

Sprout, Waldron & Co., Inc.

Pressure Tight Rotary Vane Feeder Valves

The development of a special series of pressure tight, stainless steel rotary vane feeder valves for handling a variety of industrial products has been announced by Sprout, Waldron.

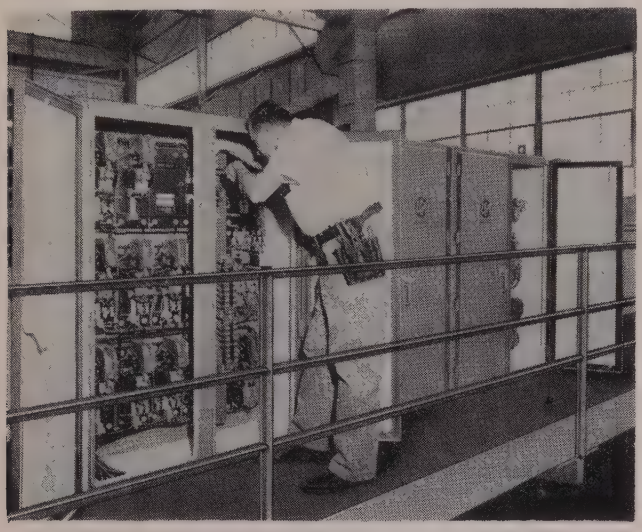
Major design features include extra heavy construction, external ribs and close tolerance fits, to provide satisfactory service under 25 p.s.i.g. internal pressure and high vacuum. The valves are designed to seal effectively against a differential pressure of 15 p.s.i. across the rotary element and to op-

erate from 0°F. to 250°F. Rotors have closed ends with piston rings and "O" ring seals.

Square D Co.

Front-Connected Control

New front-connected controllers which eliminate the need for back aisle space on crane walkways have been announced by EC&M Division of Square D Co. All wiring and control components are accessible from the front, with ample working space inside the cabinet. Only one man is required for maintenance.



Front-connected control

The new EC&M controllers can save up to 20 in. of catwalk width. They are 10 to 15% lighter than equivalent controllers with conventional wiring, providing a reduction in crane weight.

Furnished with 2, 3, or 4 decks to suit headroom requirements, the new front-connected controllers are available for single-motor d.c. drives up to 225 hp.

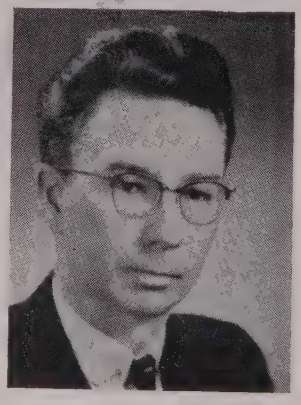
For details, write for Bulletin 6121 from Square D Co., EC&M Division, 4500 Lee Road, Cleveland 28, Ohio.

A. E. Staley Mfg. Co.

Appointment

Promotion of W. C. "Bill" Gallagher to southern manager for paper industry sales of the A. E. Staley Mfg. Co. was announced by R. L. Schuerman, manager of paper industry sales for the Decatur corn, soybean, and chemical processing concern.

Mr. Gallagher had been paper industry sales technical representative in the Southeastern states. In his new position he will direct the Staley field organization serving the paper, corrugating, building materials and related industries in the southern U. S. He will continue to headquarter in Charlotte, N. C.

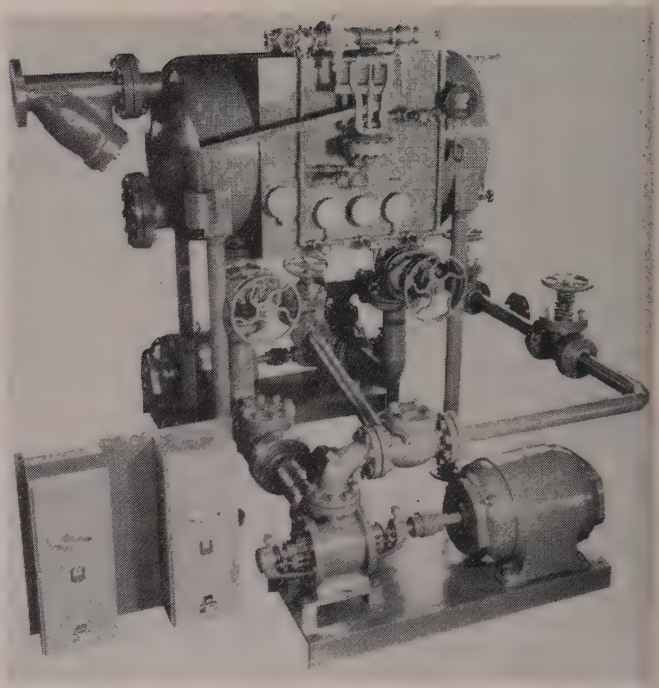


William C. Gallagher

Stickle Steam Specialties Co.

Economical Boiler Return System

A new boiler return system said to save fuel and steam, permits high pressure boilers and steam processing units to operate at top efficiency.



Duplex boiler return system

Known as the Duplex boiler return system, it automatically maintains a positive differential between steam supply and return lines. Condensate and air are quickly evacuated from the steam line, permitting processing units to operate continually at full capacity. Steam requirements are reduced because condensate is returned to the boiler usually within 10 degrees of the temperature of saturated steam.

More information from Stickle Steam Specialties Co., 2215 Valley Ave., Indianapolis 18, Ind.

Stone Container Corp.

New Corrugated Box Plant

Stone Container Corp. will open a new corrugated box plant at 1900 Foss Park Ave., North Chicago, in early April.

Robert M. Briggs, general manager of Stone Container's 42nd Pl. plant, also will supervise the new operation. Alvin Blue will serve as assistant general manager and sales manager, Avery J. Stone as plant manager, and James E. Meehan, assistant sales manager.

Russel! R. Kynoch has been named general sales manager of the Chicago Corrugated Division, succeeding Mr. Blue.

Testing Machines Inc.

PATRA Fluff Tester

TMI announces the availability of a three-page brochure describing the new PATRA fluff tester. This tester was developed by the Printing, Packaging, and Allied Trades Research Association, Surrey, England, after it was seen that a large quantity of fluff was removed from paper when it was passed through the printing machine in contact with a dry blanket. This principle has been used in the construction of the tester. An interesting item for paper manufacturers, packaging personnel, and printers.

For complete details write to Testing Machines, Inc., 72 Jericho Turnpike, Mineola, N. Y.

Power Operated Circular Sample Cutter

TMI announces a new data sheet which illustrates and describes the power operated circular specimen cutter.

This cutter is the answer to the growing demand for a fast, accurate, preparatory instrument for circular samples. The unit, besides being faster and more accurate is much

safer to handle than the present manually operated cutters.

For complete details write to Testing Machines, Inc., 72 Jericho Turnpike, Mineola, N. Y.

Texas Gulf Sulphur Co.

Operations at Nopalapa Suspended

The world's leading producer of sulfur, suspended its operations at its Mexican sulfur plant at Nopalapa, in the State of Vera Cruz.

The Nopalapa plant is a small producer and its cost of operation is high relative to the company's other more efficient producing units.

Union Carbide Plastics Co.

North Carolina Sales Office

A new sales office in Greensboro, N. C., has been established by Union Carbide Plastics Co., Division of Union Carbide Corp., effiective immediately. It is located in the Guilford Building, Room 712, Greensboro, N. C

C. S. Shoemaker, a technical representative in the company's south atlantic region since 1950, will be located in the new Greensboro office.

Fibrous Resins for Speciality Papers

Fibrous vinyl and styrene resins are now available in developmental quantities for tests in specialty paper applications, it was announced today by Union Carbide Plastics Co, Division of Union Carbide Corp.

Microphotograph of bakelite-brand fibrous resin (370×). Fine fibrils can be seen extending from the main fiber bundles

The new Bakelite fibrous resins have the appearance of cellulose pulp. Fibers are very irregular in structure with many fine fibrils extending out from the main fiber bundle. Diameters vary from 2 to 200 μ and lengths range from very short to a maximum of $^3/_{16}$ in. The vinyl resin is designated VXKA-6112 and the styrene resin, SXKA-0121.

Current tests indicate that the fibrous resins may find application in laminates, pulp and paper molding, and in asbestos paper for improved bonding.

Non-paper applications include reinforcement of glass fiber mats and bonding of nonwoven textiles.

United States Gauge

Folder on Gauges and Instruments

"Gauges and Instruments for the Process Industries" is the title of a four-page bulletin issued by the USG.

Featured in the bulletin are USG's pressure and vacuum gages (USG Supergauge and Solfrunt series), indicating pneumatic controllers, and pneumatic transmitters. A schematic shows the installation of a USG indicating pneumatic controller in a typical "cascade" control system. This device has found wide application in sensing and indicating pressure or temperature.

Copies of bulletin 3015 may be obtained without obligation by writing to United States Gauge Division, American Machine and Metals, Inc., Sellersville, Pa.

United States Gypsum Co.

New Chipboard Plant for Jacksorville

United States Gypsum will start construction of a new chipboard plant in Jacksonville, Fla., this spring

The multimillion-dollar plant is U. S. Gypsum's fourth facility to be started in the southeast in the last 12 months, and the second in Jacksonville. The site is a 19-acre plot adjacent to the company's existing gypsum manufacturing plant at 6825 Evergreen Ave.

Virginia Smelting Co.

Appointment

George V. Rittenhouse has been appointed to the position of District Manager, Industrial Sales Division, with headquarters at 270 Madison Ave., New York City.

Mr. Rittenhouse is an active member in TAPPI, Chemists' Club, and Salesman's Association of the ACI.

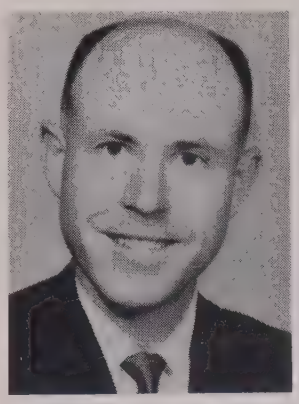
George V. Rittenhouse

Western Precipitation Div./ Joy Manufacturing Co.

Appointments

William E. Archer has been promoted to the position of manager of research and development and Robert F. Stewart has been appointed as vice-president and assistant general manager of Western Precipitation Div. in Los Angeles, Calif.

Western Precipitation, founded in 1907, is a leader in the dust and fume control equipment industry. Recently it became a division of the Joy Manufacturing Co, Pittsburgh, leaders in the coal machinery field and in air moving and cleaning equipment for all industry.



William E. Archer

Robert F. Stewart

General

Goodyear Tire and Rubber Co.

High-Speed Tire Testing

Electronics and high-powered motors help to torture-test a tire at 510 m.p.h.

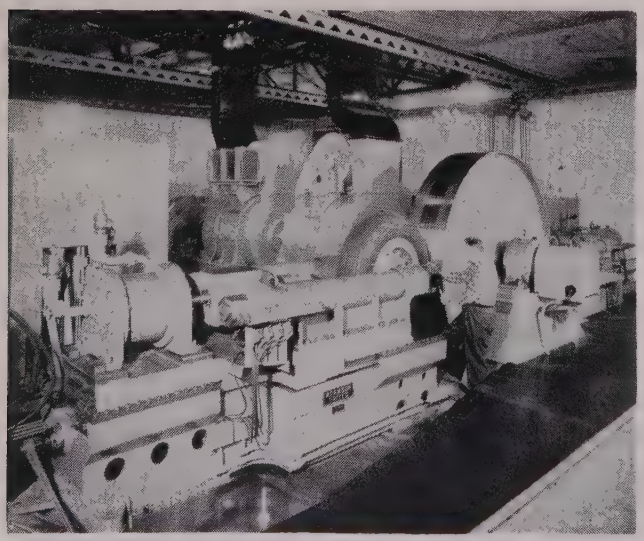
A Goodyear technician monitors a high-speed tire test on closed-circuit television

This record tire-testing speed was reached on a giant, $2 million engineering facility—known as a multistage dynamometer system—installed at the Goodyear Tire & Rubber Co.

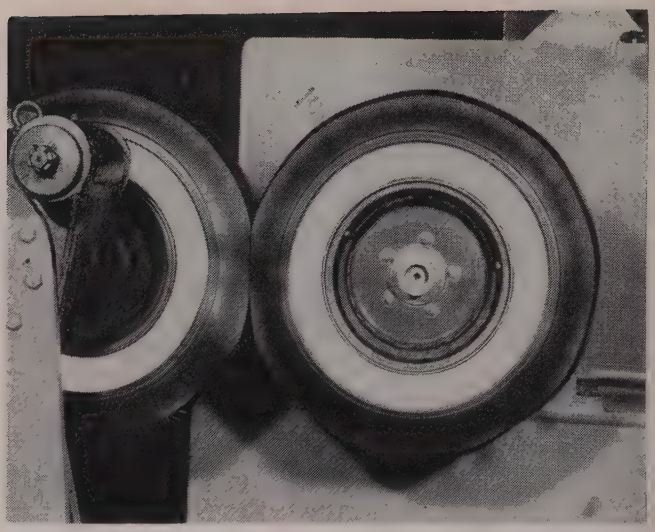
The new installation, only one of its kind in the tire industry, enables Goodyear technicians to develop, test, and qualify tires for the highest performance jet aircraft, and the fastest racing cars. As a result of the machine's great capabilities, engineers are able to learn what causes a tire to fail at ultra-high-speeds, and therefore to develop even better high-speed tires for both airplanes and automobiles.

Because of the physical dangers involved in running tires at such speeds, the actual testing is viewed on closed-circuit television.

The machine, built by the Adamson-United Co. of Akron, has two separate units and is capable of testing either airplane or automobile tires.



An airplane tire in contact with the 10-ft high flywheel, which duplicates the stresses and strains of a specified take-off



The "waves" in these tires show what happens just seconds before a tire blows out at ultra-high-speed

One side of the machine features a unique "tire-on-tire" test facility, only one of its kind in the country. On this unit, two tires are pressed together, tread to tread, to duplicate actual load conditions, and then driven at surface speeds that can be boosted to more than 500 m.p.h.

The second unit features a huge flywheel, 10 ft. in diameter, with a tire carriage on each side. Used primarily for testing airplane tires, it is capable of surface speeds of 320 m.p.h.

Loads of better than 80,000 lb. and tire sizes from 16 in. to over 6 ft. in diameter can be accommodated.

A.I.Ch.E.

The American Institute of Chemical Engineers will hold a four-day joint meeting with the Instituto Mexicano de Inginieros Quimicos at the Hotel Del Prado, Mexico City, June 19–22, F. J. Van Antwerpen, A.I.Ch.E. secretary, has announced. It will be the first joint meeting of the two societies and the occasion will be the first time in the 52-year history of the Institute that it has met outside the continental United States, except for Canadian meetings.

Cotton Linters in Papermaking

Wide use of cotton linters pulp in papermaking is indicated as a result of the latest findings of a continuing research project by Buckeye Cellulose Corp.

According to Karl A. Jurbergs, electron microscope shows that linters and staple cotton have essentially the same surface structure even though they are separate and distinct fiber growths.

On the surface of each are cellulose bundles of fibrils which form ridges running at an angle around the fibers. The Buckeye studies reveal that commercial pulping processes frequently destroy the surface ridges of the fibers. The elimination of ridges appears to be more pronounced in the staple cotton fibers.

Although linter pulp fibers usually have sufficient surface fibrils, interfiber bonding is hampered by the stiffness of the split-off fibrils and by the resistant surface ridges encountered on these fibers. The inability of the linter fibrils to collapse easily prevents untreated linter pulps from developing the necessary strength properties.

Through chemical modification, the surface structure of linters can be changed sufficiently to improve their beating characteristics. At the same time chemical modification improves the degree of hydration and increases the swelling and conformability of the fibers. Controlled partial hydroxyethylation affords this improvement in bonding characteristics without a consequent fiber strength loss.

Poplar Popular Pulpwood

Poplar, once known as a "weed" tree, is becoming increasingly popular as pulpwood and, under certain conditions, is making a better quality paper than spruce, K-C woodlands department reports.

Better opacity, tearability, and durability are found in poplar paper. Some of these qualities are inherent in the wood, but it also took advancements in technology and a great deal of experimental work by Kimberly-Clark to make it possible to handle the wood in the pulpmaking process.

As a result, Kimberly-Clark is the first to use 100% poplar in the groundwood process and the first to use rough poplar for groundwood. There still are some problems, particularly in debarking, and research and development are investigating such things as newer mechanized debarkers for use in the mills as well as the portable debarkers that can be used anywhere in the woods.

Another result is that Wisconsin and Upper Michigan are gaining: Kimberly-Clark has replaced 75,000 cords of spruce with 95,000 cords of poplar trucked to the corporation's two major bookpaper mills at Kimberly and Niagara.

It has been no simple task, this making of poplar popular as pulpwood. Nor has it been cheap. Kimberly-Clark always has used some poplar in groundwood pulp but it was in small amounts.

There were many problems to solve before the change to 100% poplar was possible. Kimberly-Clark had to learn to grind it so it made suitable pulp. The pulp had to be cleaned. Poplar pulp is dirty. It couldn't be used without the cleaning process. And a way to bleach it had to be found, and at a low cost. Kimberly-Clark experimented and improvised and added to existing grinding equipment and to centrifugal cleaners. It was no quick solution. In fact, the "de-dirting" problem alone has long been a research project. When the problems involved in using poplar for groundwood pulp appeared to be licked, management had to make its big decision. To switch from spruce to poplar in groundwood pulp processing would mean additional equipment involving a substantial capital investment. Could it be justified? In one mill alone it would run into a million dollars. Management did decide to take the risk. The decision was right, and today the dollar return is right, too, and the quality paper, for which Kimberly-Clark long has been known, is even better.

Poplar has a much shorter, much weaker fiber than spruce and generally has been used as pulpwood filler. With the solution to grinding, cleaning and bleaching problems, the paper men found that the wood apparently has some binding qualities that help to make a better sheet of paper despite the short fibers. What are they? As yet no one knows.

The solution to the problems involved in using poplar for groundwood pulp has greater impact than just the change from spruce to poplar. It has spurred an interest in other hardwoods. At present, K-C has learned to grind poplar but experiments and trials continue. Kimberly-Clark's associate, the Coosa River Newsprint Co., already has started to use some gum in its process. A bright future may just be beginning for all so-called "weed" trees.

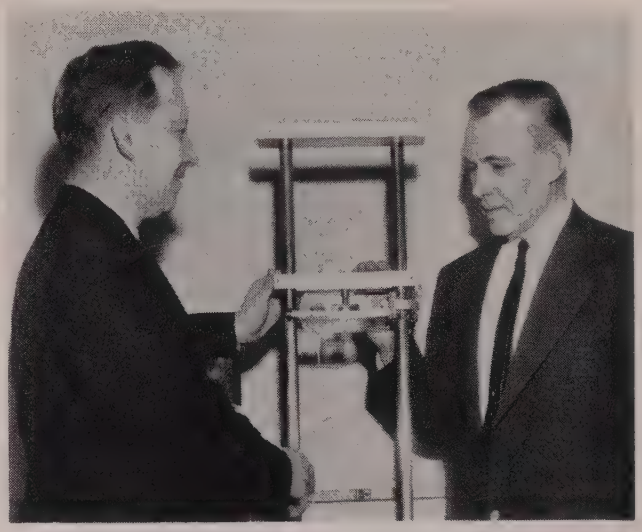
Enlarged Microfilm Prints

Bauchet & Cie., well-known manufacturers of photographic and diazotype materials in France, have perfected a silver photographic stabilization process named Rollacopy, which opens the way to fast and inexpensive making of readable and reproducible enlarged prints from microfilm with the high resolution power of silver photography suitable for quantity production as well as for single prints.

Rollacopy paper can be printed in any overhead microfilm reader. No darkroom is required. Exposure times are between 1 and 30 seconds. An inexpensive developing unit takes care of development and stabilization of the prints in about 10 seconds: Rollacopy paper is available on opaque and translucent base stock. Owing to the high reprint opacity of the silver image the prints make excellent originals for reprints by all diazo or blueprint processes. Rollacopy is being introduced in the U. S. and Canada by Andrews Paper & Chemical Co., P. O. Box 528, Great Neck, N. Y.

Glass Container Manufacturers Institute, Inc.

The Packaging Research Laboratory maintained by the Glass Container Manufacturers Institute has recently completed a move to enlarged quarters on the campus of Michigan State University at East Lansing.



John G. Turk (left), and A. J. Panshin (right) inspect equipment in the new quarters on the MSU campus into which the Packaging Lab. has just moved

Upon the recent completion of a new University building at 1405 South Harrison Road in East Lansing, the GCMI laboratory moved onto the MSU campus, occupying some 3500 sq. ft. in the south wing of the new building.

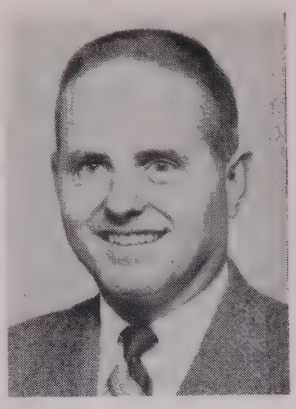
Pulp & Paper Research Centre, Inc.

John Lewis named Technical Director

John Lewis, former Head of the Paper Engineering Department, Lowell Technological Institute, has been appointed Technical Director of the Pulp & Paper Research Centre, Inc., Lawrence, Mass.

The Pulp & Paper Research Centre, Inc., is an organization comprising a fully equipped pilot plant, laboratory, and engineering department. Staffed with experienced personnel, it is engaged in process and equipment research and development both for John W. Bolton & Sons, Inc., with which it is affiliated, and independently for the pulp and paper industry and its suppliers.

Mr. Lewis brings to the Pulp & Paper Research Centre a broad background of close association with the industry. From 1948 to 1952 he was Associate Professor of Chemical Engineering in the Pulp and Paper Section at the University of Maine. During this time he co-edited Volumes I and II of the University of Maine Lectures on Pulp and Paper with Professor Lyle C. Jenness. Since 1952 he has been a Professor and Head of the Paper Engineering Department at Lowell Technological



John Lewis

Institute, Lowell, Mass. He received his B.S. and M.A. degrees in Chemical Engineering from the University of Maine.

Well known in the pulp and paper industry, Mr. Lewis is presently chairman of the New England Section of TAPPI, vice-chairman of the Chemical Engineering Section, Engineering Division of National TAPPI, and also serves on the TAPPI Education Committee. He is a member of the American Institute of Chemical Engineers and a registered professional engineer both in Massachusetts and Maine.

American Standards Association

The average American worker, statistically safer on the job than at home or on the roads, will enjoy an added margin of safety as the result of the recent revisions to the American Standard covering safety glasses, respirators, and hard hats. The newly revised American Standard Safety Code for Head, Eye, and Respiratory Protection include the addition of plastic eye protectors, and an increase in strength requirements for eye protection. One section contains 86 definitions of words common to this field. In general, the code has been brought up to date with modern production methods working environments and available safety equipment.

American Standard Safety Code for Head, Eye, and Respiratory Protection, Z2.1-1959, 48 pp., is available at $3.00 a copy from the American Standards Association, Dept. PR121, 70 East 45th St., New York, 17, N. Y.

OBITUARIES

Reuben B. Robertson, Jr.

Reuben Buck Robertson, Jr., president of the Champion Paper & Fibre Co., Hamilton, Ohio, was struck and killed by an automobile while en route to his home in Glendale, Ohio, on March 13, 1960.

Mr. Robertson was born in Asheville, N. C., on June 27, 1908, and graduated as a chemical engineer from Sheffield Scientific School, Yale University, in June 1930.

He entered the employ of Champion in its engineering department, subsequently becoming president of the company.

Mr. Robertson was Deputy Defense Secretary of the United States from July 12, 1955, to March 26, 1957, under Charles Wilson.

He is survived by his wife, the former Margaret Watkins, and six children, Reuben B. Robertson III, Daniel H., Peter Thompson, Margaret Laurens, Louisa Hope, and George Watkins.

Edward H. Voightman

Edward Hugo Voightman, manager of the New Products Development of the Research and Development Department of Kimberly-Clark Corp., Neenah, Wis., died from a heart attack on Jan. 20, 1960.

Dr. Voightman was born in Hoboken, N. J., on June 28, 1907. He graduated from the University of Wisconsin (1930) and The Institute of Paper Chemistry (1933).

He joined the Kimberly-Clark organization in 1933, in the research and technical control departments.

Dr. Voightman was formerly a chairman of the Lake States Section of the Technical Association of the Pulp and Paper Industry.

He is survived by his wife, Cecille, a son Edward W. Voightman, Jr., a junior at the University of Wisconsin; a brother, Walter Voightman of Beaumont, Tex., and a sister Mrs. Hildegard Stephani, Barrington, N. J.

Joseph B. Homan

Joseph B. Homan, sales representative for A. E. Staley Manufacturing Co. of Decatur, Ill., died at Mobile, Ala., on Nov. 13, 1959.

Mr. Homan was born in Pontotoc County, Miss., on April 7, 1902, but he and his wife, Mrs. Leona R. Homan, who survives him, lived in Mobile for the past 20 years, at 212 Summerville Court, Mobile 17, Ala.

Prior to Mr. Homan's affiliation with the A. E. Staley Manufacturing Co. in March, 1945, he was employed by the Union Bag Co., later the St. Regis Paper Co., in Tacoma, Wash., the Champion Paper & Fibre Co., in Canton, N. C., transferring to the new mill in Pasadena, Tex., and with the Hollingsworth & Whitney Paper Co. in Mobile, Ala.

Mr. Homan has been an associate member of TAPPI since 1946.

Edwin W. Schoenberger

Edwin W. Schoenberger, Dean of Students, The Institute of Paper Chemistry at Appleton, Wis., died of a cerebral hemorrhage on Feb. 29, 1960, at the age of 52.

Dean Schoenberger, a native of Springfield, Ohio, attended Defiance College (Defiance, Ohio) and Wabash College (Crawfordsville, Indiana), where he received his B.A. degree. He obtained the M.A. degree from the State University of Iowa and did further graduate work, at Northwestern University.

He taught corrective speech at Defiance College (1934–36), College of Commerce at Northwestern University (1936–38), and Iowa State College (1938–39) before joining the faculty of Lawrence College in Appleton, Wis., as a professor of speech (1939–52). In 1940, he became a member of the faculty of The Institute of Paper Chemistry as professor of speech and communication.

In 1952, Mr. Schoenberger was named Dean of Students at the Institute. In 1956, he became chairman of the Department of General Studies, and in 1959 he took on additional responsibilities as curator of the Dard Hunter Paper Museum at The Institute of Paper Chemistry. Among other civic positions, he served as a member of the Selective Service Board for several years, and in 1954–55 he was President of the Appleton Rotary Club.

Reuben B. Robertson, Jr.

Edwin W. Schoenberger

TAPPI DIVISIONS AND COMMITTEES

Reports of Activities

Subcommittee—Forest Biology Committee

Subcommittee No. of the TAPPI Forest Biology Committee met at 9:30 a.m., Jan. 22, 1960, at the Palmer House in Chicago. The meeting was called by P. N. Joranson to review and revise digests, previously prepared, of selected wood and fiber properties with regard to their effects in processing and upon the properties of paper and paperboard.

Those in attendance included the following:

P. N. Joranson, *Chairman*
B. K. Mayer
E. F. Thode
R. F. Sultze
M. Y. Pillow
J. R. Salvesen
F. E. Pollock
A. J. Winchester
M. G. Lyon

Mr. Lyon was asked to serve the meeting as secretary, and agreed to do so.

Agenda

After a brief discussion, it was agreed to use an agenda prepared by Mr. Joranson, with the understanding that it would be modified in the order of the items discussed to suit the travel schedules of the attendees. The agenda suggested by Mr. Joranson follows:

1. Introductions and announcements (A. J. Winchester: Seattle conference).
2. Consideration and action on each collation draft, in order listed in letter of November 18.
3. Plans for publication of the report on wood and fiber properties.
4. Improvement of wood and fiber property tests on small samples from living trees—how can subcommittee best serve this need?
5. New activity.
6. Subcommittee report to parent committee at New York in February.
7. Next subcommittee meeting, at Seattle, in August.

Seattle Conference

Mr. Winchester briefly brought the committee up to date on the plans for the TAPPI Forest Biology Conference scheduled for Seattle on Aug. 24–27, 1960. The dates are set to accommodate people attending the Alkaline Pulping Conference in Portland, Aug. 22–24, 1960, and those attending the World Forestry Congress in Seattle beginning Aug. 29, 1960.

Mr. Winchester reported that the committee has decided on preregistration so the size of the conference can be kept to the 300 that can be accommodated by the hotel. Announcement of the conference will be made in the May and June issues of the *Journal of Forestry*, and *Tappi* magazines.

Considerable discussion evolved around the date to schedule a meeting of Subcommittee No. 2, in order to avoid possible conflict with the TAPPI sessions at the Alkaline Pulping Conference. The committee finally agreed that they would favor holding a luncheon banquet at Seattle on Thursday noon (August 25) rather than an evening banquet. This would make it possible for Subcommittee No. 2 to meet on Thursday evening. The committee does not wish to meet before Thursday because of conflict with the TAPPI Portland meeting.

Order of List of Wood and Fiber Properties

It was suggested that the wood and fiber properties be included in a single list rather than a list of wood properties and a list of fiber properties separately. This was agreed without dissent.

Mr. Salvesen suggested that No. 5 on the list, "Chemical Analysis of Pulp," be deleted because the method of the pulp isolation so heavily affects the results as to be of little use to the forest geneticist. Dr. Thode expressed the view that there is need to evaluate the isolated fiber. Mr. Salvesen suggested the use of standard micro methods of evaluating the wood, but without true pulping. Dr. Joranson suggested we defer the discussion until item No. 4 of the agenda. Dr. Thode then moved that we delete item No. 5 from the collation list, but consider it actively in future work on meaningful small-scale tests (agenda item No. 4). Motion carried and this item was stricken from the collation list.

The question was raised concerning the addition to the list of wood and fiber properties of: "the proportion of nonfibrous elements in the wood." This is an important consideration in the case of hardwoods. Mr. Lyon expressed the opinion that the list of wood and fiber properties originally made was slanted particularly toward southern pine in the interests of simplicity, and because the bulk (but not all) of forest genetic activity centers on the southern pines. A quick check on the available minutes of previous meetings indicated no written record of a limitation to southern pines or conifers. General discussion indicated the group, as a whole, wished to include the hardwoods when publishing data on wood and fiber characteristics as related to processing and paper and board quality. Lyon moved that the objective be kept broad enough to include the hardwoods, and that the committee include in the list of properties, "the proportion of nonfibrous elements." The motion was passed.

The list as it has been modified now is:

1. Wood density or specific gravity.
2. Proportion of springwood and summerwood.
3. Growth rate.
4. Chemical composition of wood.
5. Fiber length (average and distribution).
6. Fiber diameter (average and distribution).
7. Cell wall thickness (average and distribution).
8. Fibrillar angle.
9. Fiber strength as it exists in the wood.
10. Bonding strength, fiber-to-fiber.
11. Knotwood.
12. Reaction wood.
13. Proportion of nonfibrous elements in the wood.

Form of Report of Wood and Fiber Properties

The form in which the final draft of the write-ups of the wood and fiber properties will be presented was much discussed. Joranson asked if the fact that this is part of a formal TAPPI project would affect the form of publication. Winchester replied in the negative. Thode suggested a special publication that could be distributed to forestry and pulp and paper schools. Joranson suggested the paper be reprinted in the *Journal of Forestry*. Joranson made a motion that the paper be published in *Tappi* and simultaneously offered for publication in the *Journal of Forestry*, and that consideration for publication be requested as soon as possible after the manuscript is available. Motion carried.

The matter of extra copies of the paper for distribution was not fully resolved, but it was decided to request TAPPI to furnish 500 preprints of the paper for distribution on presentation of the paper at Seattle. Decision on presentation at Seattle was secured on motion by Thode, seconded by Pollock, that the paper be presented at the Seattle forestry meeting. Motion carried. The committee expressed preference for having Dr. Joranson deliver the paper, but he felt it would be preferable to have a pulp and paper technologist give the paper, if one from the committee can attend the meeting.

Consideration of Each Collation Draft

The bulk of the meeting was devoted to a discussion of the collation drafts pertaining to the individual wood and fiber properties. Suggestions for change or improvement were made in many cases.

New Tests for Wood or Fiber

Time did not allow a discussion of sufficient length to chart fully our committee action on this vital field. All members thought this an area where help could be given to the forest geneticists.

After brief discussion it was agreed to:

1. Write principal laboratories doing testing work on small wood samples to compile a list of available methods. Asked Joranson to undertake this task.
2. Make the list of methods available to those laboratories or individuals submitting data themselves.
3. Consider the possibility of undertaking a TAPPI project to study the applicability and reliability of new test methods before advocating their use in connection with forest genetic studies.

Meeting adjourned at 4:40 p.m.

M. G. Lyon

Internal Tearing Resistance

The first meeting of the joint ASTM-TAPPI Task Group on Internal Tearing Resistance of Paper was held at Janssen's Restaurant in New York City on Sunday evening, Feb. 21, 1960. The purpose of the meeting was to discuss a proposed revision of TAPPI Standard T 414 m and the corresponding ASTM Designation D-689. The proposed revision was based on suggestions received in connection with the recent interlaboratory studies of the internal tearing method.

Numerous changes in the first draft were recommended by the task group members, and the chairman was directed to prepare a second draft incorporating these changes. In addition, task group members will investigate the possibility of determining bearing friction under operating conditions.

A task group meeting is tentatively planned for Atlantic City to be held in conjunction with the ASTM Annual Meeting.

Additional suggestions from TAPPI or ASTM members will be appreciated and should be sent to the chairman.

T. W. Lashof, *Chairman*

Air-Leak Smoothness

A brief meeting of the Joint Task Committee of the Graphic Arts Committee and the Paper Testing Committee was held at the Hotel Commodore, New York City, on Tuesday, Feb. 23, 1960. The chairman reported renewal of the research appropriation, approval for publication in *Tappi* of the report on the results of the first phase of the study, and the completion of the preparation of samples for the general and, we hope, final, round robin on air-leak smoothness.

On the basis of the results of this general round robin, as well as those of the round robins on paperboard and mimeobond, the committee will revise TAPPI Suggested Method T 479 sm-48. Any suggestions from TAPPI members will be appreciated and should be sent to the chairman.

T. W. Lashof, *Chairman*

Container Testing Committee

The TAPPI Container Testing Committee Meeting was held at the Commodore Hotel, New York, N. Y., on Feb. 22, 1960. The meeting was called to order at 9:00 a.m. by the chairman, M. J. Clark. Those in attendance were:

M. J. Clark, *chairman*, Inland Container Corp.
A. W. Hoffman, *vice-chairman*, Continental Can Co., New York, N. Y.
G. C. Lecky, *secretary*, St. Regis Paper Co.
B. Q. Haynes, B. F. Perkins & Son, Inc.
J. J. Kipnees, Atlantic Gummed Paper Corp.
Earl Knapp, W. Virginia Pulp & Paper Co., H. & D. Div., Sandusky, Ohio
J. Limerick, Bathhurst Power & Paper Co., Montreal
W. B. Lincoln, Jr., Inland Container Corp.
C. S. Macnair, Acme Steel Co.
Ked Martin, Olin-Mathieson Chemical Co., Monroe, La.
G. W. Menkes, Testing Machines, Inc.
T. J. Muldoon, Fibre Box Association
H. G. Nelson, Owen-Illinois (Forest Products)
C. H. Root, Continental Can Co., Van Wirt, Ohio
Henry W. Seibel, Crown Zellerbach Corp., Gaylord Cont. Div.
R. E. Swingle, Acme Steel Co.
Dale Wolvin, Weyerhaeuser Co.
Percy Cox, Consolidated Water Power & Paper Co.
K. A. Wohl, Thatcher Glass Mfg. Co., Elmira, N. Y.
Maurice Burnston, TAPPI
C. E. Brandon, Chairman, Testing Division

A new member of the committee is Percy Cox of Consolidated Water Power & Paper Co.

Minutes of the previous meeting were accepted as published.

Subcommittee reports were as follows:

I. Flat Crush, H. G. Nelson, chairman: Mr. Nelson commented on a tenative write-up of the flat crush method which had been submitted by Hugh Johnson. It was the consensus of the committee that this method should be rewritten to be more specific as the chairman pointed out that these methods were mainly intended to be used as referee methods and as such should definitely spell out as many things as possible.

The subcommittee chairman will therefore rewrite this method incorporating the suggested changes and circulate it among the subcommittee members for comment and unofficial ballot.

The revised procedure will then be sent to the committee secretary who will have it circulated to the full committee prior to the next meeting. The committee members can then be familiar enough with the procedure to discuss it in detail and approve a final draft to be sent out for letter ballot.

Mr. Brandon, chairman of the Testing Division, stopped in for a visit, and the matter of letter ballots was brought up to him. He promised to get clarification on: (1) whether $^3/_4$ of voting members or $^3/_4$ of all committee members was necessary to approve a Standard, and (2) whether it would be proper to put a not voting space on a letter ballot in addition to the affirmative and negative spaces.

Mr. Brandon also suggested that if a revised method is an improvement over the present method, although there were still major points of conflict, the new method should be put through, incorporating the changes that were acceptable and not changing the controversial points. These could then be changed in the future when the conflicts were resolved.

II. Burst Test, A. V. Grundy, chairman: Mr. Grundy requested Mr. Knapp to give the committee report.

Mr. Knapp stated that the round robin, that had been talked about in the last meeting, to determine the difference between new and old type diaphragm and plate had not gotten under way as yet but that he had had correspondence

with Mr. Bicking of the Statistical Committee on the proper design of this experiment and had settled on the proper number of samples.

It was decided that the clamping pressure would be as used in each individual laboratory but that it would be defined by that particular laboratory. One sample of double wall would be used (either 275 or 350 lb.) and the flute to be used would be at the discretion of the task force.

The tentative method of test for bursting test for liner board would have the scope changed to exclude corrugated board and solid fiber. This method would then be sent to the committee secretary who would have it sent out to the full committee for comments.

III. Compression Test, Ked Martin, Chairman: Mr. Martin stated that his committee's revision had been sent out to the committee several times and had never received sufficient affirmative votes to be approved. The main objections being fixed versus floating platens, 180 or 90° bend, number of tests and the scope of the test.

The chairman stated that the old standard was dated November, 1945, and should be brought up to date. He mentioned again that TAPPI Standards are referee methods only and as such need not comply with each individual laboratory's operating procedure.

It was decided to rewrite the old standard, incorporating only those changes that had very little opposition and make necessary editorial changes. This method together with a letter of explanation stating that the method is old and needs certain revisions to bring it up to date will be sent to the Secretary and he will have the revised standard sent out to the committee for letter ballot.

The chairman pointed out that a method used for years does carry a lot of weight because of test history and familiarity of many people with the test. If we can use the old method as a basis making necessary changes slowly as needed without completely revising the tests we can perform a service to the industry without causing undue confusion.

The chairman reported on the status of the methods under the jurisdiction of this committee which are mainly the methods in the 800 series. In many instances ASTM has later methods than we have and we should review these ASTM methods to see if we should adopt their revisions.

Mr. Clark then introduced the new chairman, A. W. Hoffman, who then appointed the new vice-chairman, G. C. Lecky, and the new secretary, J. J. Kipnees.

Mr. Hoffman appointed a task force of C. Root, chairman, W. B. Lincoln, Jr., and K. Wolvin, to review ASTM drop, puncture and drum tests to see if they could, with minor revision, be sent out to the committee as a letter ballot for acceptance as TAPPI Standards.

Another task force consisting of H. Seibel, chairman, G. Maltenfort, and C. Zusi, are to do the same for the ASTM Standards on conditioning of paperboard and containers. The chairman was to contact the division chairman, Mr. Brandon, to see if the ring crush test came under the jurisdiction of our committee.

Mr. Hoffman then thanked Mr. Clark for the good work he had done as chairman of the Container Testing Committee and Mr. Clark was given a rising vote of thanks by the members of the committee.

The next meeting will be in Toronto, Canada, Oct. 10–13, 1960.

Meeting was adjourned at 12:30 p.m.

G. C. Lecky, *Secretary*

Local Section Operations Committee

The Local Section Operations Committee met on Feb. 24, 1960, in the East Ball Room Parlor of the Hotel Commodore, New York, N. Y. The meeting was called to order by J. W. Field at 4:00 p.m. The following were in attendance:

P. Bersano, Italian Section
W. D. Boggess, Indiana District, Ohio Section
G. K. Boger, Jr., Delaware Valley Section
A. J. Chase, Maine-New Hampshire Section
C. E. Eberly, Indiana District, Ohio Section
J. W. Field, TAPPI Staff
R. A. Flick, Southeastern Section
W. O. Kroeschell, Kalamazoo Valley Section
J. Lewis, New England Section
R. F. Miller, Virginia-Carolina Section
P. E. Nethercut, TAPPI Executive Secretary
F. W. O'Neil, Empire State Section
P. Page, Eastern District, Empire State Section
V. E. Perry, Ohio Section
E. N. Poor, Maine-New Hampshire Section
A. L. Saindon, Jr., Delaware Valley Section
J. F. Theriault, New England Section
J. W. Wendall, Jr., Eastern District, New England Section

Fall Tour of Dr. Stockman

Mr. Field read a telegram from Norval Magnusson, chairman of the Pacific Section, which stated that Dr. Lennart G. Stockman of the Swedish Cellulose Industry Central Laboratory would be speaking at the Pacific Seminar Sept. 19–23, 1960. A tentative speaking schedule to propose to Dr. Stockman was set up as follows: Delaware Valley Section, September 16; Pacific Seminar, September 19–23; Golden Gate Section, ?; Empire State Section, Central District, September 30 or October 7; Ohio Section, October 4 or 6; Southeastern Section, October 7 or September 30. It was agreed that other sections not represented at the LSO meeting might be worked in.

Petition of the Golden Gate District for Section Status

The petition of the Golden Gate District of Pacific Section, along with the supporting letter from the chairman of the Pacific Section, was read to the committee. This material is contained in Exhibit A of these minutes.

Mr. Flick moved, seconded by Mr. Lewis, that the Golden Gate District of the Pacific Section be accorded Local Section status. The motion was passed unanimously.

Speakers

Considerable discussion took place as to what services National Headquarters might provide in regard to speakers for local programs. The group was unable to reach any degree of unanimity on a number of suggestions, among which were: (1) to provide a speaker, or speakers, to make national tours during the year, and (2) to provide a rating service of speakers who appeared at Local Section meetings.

It was generally agreed by the group, therefore, that TAPPI should continue to publish at frequent intervals, a list of speakers which had appeared at Local Sections without any attempt at rating them. Further, when a group did have an exceptional speaker, they would communicate this information informally to TAPPI Headquarters with the thought in mind that these men could then be recommended to other groups when, as, and if requested.

Review of Recent TAPPI Executive Committee Action

A statement of Association policy on rebates (appended hereto as Exhibit B) as adopted by the TAPPI Executive Committee at their February 21 meeting was distributed to members of the Local Section Operations Committee.

It was next announced that the Executive Committee had voted to retain Fuller, Miele, Inc., as professional counsel on member relations and information. Appendix C outlines the scope of this program.

Mr. Nethercut announced the appointment of J. W. Field as Local Section Assistant by the Executive Committee. In this capacity, he serves as an official contact between the local sections and National TAPPI.

Mr. Nethercut also stated that Executive Committee

members had been urged by TAPPI President James R. Lientz to make a determined effort to attend Local Section meetings in their areas.

Local Section Project Fund

The group was reminded by Mr. Field that a special fund exists for section activities in situations where the section cannot itself underwrite the cost. Requests for such monies should be directed to his attention at TAPPI Headquarters. Mr. Nethercut cautioned the group that requests should not be made to pay the travel expenses of speakers who could very well obtain the necessary finances from their companies or institutions.

Local Section Publicity

The new Local Section Newsletter was called to the attention of the group, as was the new Association Newsletter. Mr. Field stated that the section publicity chairmen were generally to be complimented on their efforts in providing material both for *Tappi* and the trade press but that several groups were still behind in their efforts.

Mr. Eberly moved for adjournment and was seconded by Mr. Perry. The meeting was declared adjourned at 5:10 p.m.

J. W. Field, *Local Section Assistant*

Exhibit A

Mr. John A. Hartsock, Chairman
Golden Gate District, TAPPI
1601 Las Plumas
San Jose, California

Dear Mr. Hartsock:

The Executive Committee of Pacific Section TAPPI at its November, 1959, meeting unanimously approved and agreed to support the desire of the Golden Gate District to petition for Section status. This action is recorded in the minutes of our Executive Committee dated November 17, 1959.

The "Manual for the Guidance of Local Sections of TAPPI" describes clearly the steps for organizing a new section but does not cover the steps required for a recognized "District" to obtain a charter as a separate Section. If there is any additional information or support that your group would like from Pacific Section, please let us know and we will help in every way possible.

Speaking for Pacific Section, we would like to congratulate you and the members of your District on the progress you have made and the aggressive programming you have undertaken. We feel that as a Local Section you will be able to serve your members even better and to more fully further the purposes of TAPPI.

Yours very truly,
Norval Magnusson
Chairman

Petition for a Section Charter for the Golden Gate District of the Pacific Section of TAPPI

To: Mr. James R. Lientz—President of the Technical Association of the Pulp and Paper Industry

We, the undersigned, representing the membership of the Golden Gate District of the Pacific Section of TAPPI, submit the following, in line with Article XII of the Constitution:

Whereas, the Golden Gate District was organized under the sponsorship of the Pacific Section of TAPPI October 8, 1957, and held its first meeting October 8, 1957

Whereas, the Golden Gate District has a membership of 147 dues paying members for the 1957–58 term and 170 dues paying members in 1958–59

Whereas, the 11 programs presented by the Golden Gate District have been well attended, averaging 105 persons per meeting

Whereas, the membership is composed of persons concerned with the technical aspects of paper and its use and who are engaged in manufacture, converting, and related industries

Whereas, the Golden Gate District is financially solvent, has operated at all times on its own funds, excluding the standard initial grant of $100 from National TAPPI, and having at the present time a cash balance of $344.55

Therefore, Be it Resolved, the Golden Gate District Executive Committee unanimously desires this petition to be considered and granted.

John A. Hartsock
Chairman
Hutton W. Theller
Vice-Chairman
Harold A. Harvey
Secretary-Treasurer
Walter R. Brandt
Recording Secretary
Dudley F. Church
Hyman L. Rammer
Wayne H. Kuefner

Exhibit B

The following statement on local section rebate policy was approved by the Executive Committee at its Feb. 21, 1960, meeting.

1. That national TAPPI retain as written Article XII, Section 4, of the TAPPI Constitution which reads as follows:

"Each local section may receive annually for local use such portion of the annual dues of its members as may be authorized by the Executive Committee, said amount not to exceed 10% of the paid association membership dues for the then current year of the members of the section."

2. That the Executive Committee authorize the rabate to be $2.00 on the current dues basis.

3. The authority for determining membership shall rest with the Local Sections with the exception that rebates be authorized by the executive secretary on the basis that:

a. The rebate claim by the Local Section is for a member of national TAPPI in good standing.

b. The member's rebate is not requested by another section which, in the opinion of the executive secretary, has a more appropriate claim.

c. In the opinion of the executive secretary the member listed is receiving some service, however small, from the Local Section.

4. In the event of conflicts between sections relative to rebates, the conflict should be resolved, if possible, by the Local Section Operations Committee. Failure to resolve conflicts at the Local Section level will be resolved by the Executive Committee upon the recommendation of the executive secretary.

Exhibit C

The Executive Committee of TAPPI approved Feb. 21, 1960, the appointment of Fuller, Miele, Inc., New York, N. Y., as professional counsel to conduct a continuing member relations and information program for the Association.

This is the same organization which handled publicity activities for our 1959 Fall Conferences, and wrote and produced our recently published career brochure. Currently, on a special contract, they are also responsible for press coverage of the Annual Meeting.

To acquaint you with the scope of the member relations program which Fuller, Miele, Inc., will undertake, we are listing below the objectives of this program and the means by which these objectives will be attained:

Objectives

1. To provide greater recognition for the accomplishments of TAPPI members.

2. To achieve greater recognition and acceptance of the Association by paper company executives.

3. To promote better understanding of TAPPI's objectives by its own members.

4. To increase the membership of TAPPI.

5. To publicize more widely the activities of the TAPPI committees and local sections.

6. To help recruit technical graduates to the pulp and paper industry.

Activities

1. Publicizing all National meetings to be held during 1960. This includes preparing the distributing releases to the home towns of all authors and chairmen, advance releases to newspapers in the meeting city, supplying "blank" releases for use by members attending meetings, providing special advance releases to the trade press, wire services, newspapers, alumni, and technical journals, as well as daily coverage of the local press during meetings.

2. Assisting in the preparation and publication of such TAPPI literature as:

a. conference programs
b. division and local section manuals
c. annual report
d. research report to company members
e. membership promotion literature
f. career guidance material

3. Maintaining trade press relations with all technical and industrial media interested in TAPPI's activities.

4. Promoting interest in and publicizing such special activities as the TAPPI project appropriations.

5. Publicizing all important decisions and significant activities undertaken by TAPPI itself or by its members.

6. Assisting in the preparation of publicity releases for magazine.

7. Publicizing special publications produced or distributed by TAPPI.

8. Assisting local sections in publicizing their meetings.

9. Assisting in the development of a speaker's program for TAPPI.

10. Undertaking special projects whenever a problem or opportunity appears.

Mechanical Engineering Committee

A regularly scheduled luncheon meeting of the Mechanical Engineering Committee was held on Feb. 22, 1960, in Parlor "E" of the Hotel Commodore, New York, N. Y.

The following were present:

Members

C. W. Cassell, C. W. Cassell Associates
J. W. Crocker, Stone & Webster Engineering Corp.
R. T. DePan, H. F. Ferguson Co.
F. C. Duvall, Black-Clawson Co.
P. A. Fasoli, C. H. Dexter & Sons, Inc.
P. H. Goldsmith, Dominion Engineering Co., Ltd.
J. C. Harper, Rice Barton Corp.
C. E. Hill, West Virginia Pulp & Paper Co.
B. M. Hutchins, Rust Engineering Co.
H. G. Ingraham, Charles T. Main, Inc.
B. L. Merriss, Oxford Paper Co.
L. A. Moore, Black-Clawson Co.
W. H. Mordo, Stone Woodward Co.
J. S. Mudgett, Strathmore Paper Co.
J. M. Piette, Union Bag-Camp Paper Corp.
W. G. Printz, Manchester Machine Co.
G. H. Spencer, Torrington Co.
J. O. Starkweather, Ebasco Services, Inc.
F. A. Taska, Clark & Vicario Corp.

Visitors

T. N. Busch, International Paper Co.
D. R. Dalzell, Jr., E. D. Jones Corp.
George Dlesk, Packaging Corp. of America
F. P. Ford, Rice Barton Corp.
G. W. Lang, Patton Manufacturing Co.
J. E. Perkins, Black-Clawson Co.
William Pittam, Stone & Webster Engineering Corp.
S. C. Williams, Dominion Engineering Co., Ltd.

The meeting was called to order at 1:30 p.m. by Chairman Mudgett, followed by self-introduction of all those present.

The first order of business concerned the program for the 15th Engineering Conference to be held at Robert Meyer Hotel, Jacksonville, Fla., Oct. 24–28, 1960.

C. E. Hill, chairman of the Paper Manufacturing Subcommittee, reported that the list of papers to be sponsored by this group has been established as follows:

1. "Uniform Nip Loading Control of Machine Calenders," J. E. Perkins, Black-Clawson Co., and Mr. Luebke, Marathon Corp.
2. "Machine Calender Roll Crowns and Pressure Distributions," Dr. Jerome W. Riese, Kimberly-Clark Corp.
3. "Mechanical Design and Installation Requirements of Trailing Blade Coater Equipment," J. P. Munton, Rice Barton Corp.
4. "Presentation of Data Sheet on Vacuum Requirements and Suggested Standards for Measuring Vacuum," Fred A. Taska, Clark & Vicario Corp.

R. T. DePan, chairman of the Pulp Preparation Subcommittee, reported that a paper sponsored by this group is currently under preparation. This paper will be presented by someone from E. D. Jones Corp. The tentative title will be: "Comparison of the Relative Effects of Various Types of Refining Equipment." The name of the author, the exact title, and an outline of the subject will be available in two or three weeks.

Chairman Mudgett advised that R. W. Brown has found it necessary to resign as chairman of the Finishing and Converting Subcommittee due to the pressure of other duties. The members were requested to submit their suggestions for a possible chairman of this subcommittee.

Chairman Mudgett will attend to sending copies of the "Guide for the Preparation and Presentation of Papers" to each of the prospective authors, as well as the schedule for submission of material.

P. H. Goldsmith, chairman of the Data Sheets Subcommittee, reported that the following data sheets sponsored by the Mechanical Engineering Committee are in process and will be available for publication in the near future:

1. Vacuum Factors for Paper Machines.
2. Recommended Standard Method for Measuring Vacuum.
3. Baromatic Leg Design.

The following suggestions for data sheet subjects were deemed to be outside of the scope of this committee and were referred back to the Data Sheets Committee:

1. Stock Retention Time for a Continuous Bleach Plant
2. Beater, Jordan, and Refiner Comparisons.
3. Sizing of Spray-Type Sulfur Burners

In answer to a question, Mr. Goldsmith explained that data sheets, or data sheet material, emanating from the subcommittees, should be directed through the vice-chairman to the Data Sheets Subcommittee. This is in accordance with the Engineering Division Policy Manual.

Chairman Mudgett pointed out the urgent need to plan a program for the 16th Engineering Conference to be held in Washington, D. C. in 1961. He called upon all members to submit suggestions for appropriate subjects for future papers and projects. He also requested that each member give serious consideration to the possibility of personally presenting a paper on a subject with which he is conversant.

It was agreed that an interim meeting should be held in the late spring—time and place to be decided later.

Meeting adjourned at 2:10 p.m.

J. C. Harper, *Secretary*

Plastics Committee

A meeting of the TAPPI Plastics Committee was held at TAPPI Headquarters in New York City on Monday, Jan. 11, 1960, at 10:00 a.m.

The following members and guests were present:

W. N. Stickel, Chairman, Texon, Inc., South Hadley Falls, Mass.
H. F. Arledter, The Mead Corporation, Chillicothe, Ohio
H. F. Foxlee, Union Carbide Plastics Co., New York, N. Y.
H. W. Fritts, Alcoa, New Kensington, Pa.
P. J. McLaughlin, Rohm & Haas, Philadelphia, Pa.
Fritz Rosenthal, Knowlton Bros., Inc., Watertown, N. Y.
R. L. Savage, Naugatuck Chemical, Naugatuck, Conn.
V. T. Stannett, College of Forestry, Syracuse, N. Y.
R. C. Sturken, Frank W. Egan & Co., Somerville, N. J.
C. J. Waechter, Waldron-Hartig, New Brunswick, N. J.

The selection of a chairman for Task Force No. 586 was discussed. Several names were suggested and the chairman will contact them before the next meeting. Chairman Stickel pointed out that if there is no interest among the present members of the task force either in volunteering for the chairmanship of this task force or in assisting in obtaining one, there is little else to do, but disband the task force. Each member had been contacted individually by Chairman Stickel before the meeting, but no one would accept the appointment.

The following progress report was offered by R. L. Savage, chairman of Task Force No. 784—Resin Identification and Content:

1. Literature Survey: Numerous articles dating back to 1940 have been reviewed. ASTM methods and Naugatuck's procedures have also been studied.

2. Qualitative Analysis: Based on the above survey, a modification of ASTM method D 833–46 T appears to be the most suitable procedure. This method requires extraction of the polymeric material from the base paper. The extract is then identified by spot tests. Confirmatory tests involving pH reactions of the polymer's pyrolysis products are also included in this procedure.

Preliminary tests on GR-S and nitrile rubber saturated paper using this procedure have been quite successful.

3. Extraction Procedure: In the quantitative analysis of resin and elastomer treated papers, complete extraction of the polymer is required. In the case of aged papers, or where cross-linking agents have been used, quantitative extraction is difficult.

Three procedures are being evaluated by our Analytical Group: (a) prolonged Soxhlet extraction with benzene; (b) extraction with di-isobutyl ketone and *tert*-butyl hydroperoxide using osmium tetroxide as a catalyst; (c) removal of the cellulose from the resin by digestion with 71% hot sulfuric acid—the fiber content is then determined colorimetrically with anthrone reagent.

4. Quantitative Analysis: To date, a satisfactory method of analysis by "wet methods" has not been determined. ASTM and other known procedures are not reliable unless the exact monomer ratios of the latices are known. Considerably more work is required on this phase of the project.

Accurate analysis can be made with a minimum of time and effort, however, by infrared techniques. A complete scheme of analysis including extraction procedures and calibration curves will be compiled for the report to be made in February.

Most of the above procedures are for the analysis of synthetic rubbers in paper products. R. N. Campen of Colton Chemical has been contacted for help in setting up procedures for determining PVA and other water-soluble resins. This work will also be included in the February report if possible.

The following progress report was offered by Fritz Rosenthal, chairman of Task Force No. 785—Internal Bond Tests:

"The objective of this project has been clarified in that it involves the selection of one test procedure out of the following three procedures: (a) the "Mullen Method," described and used by Texon, Inc.; (b) the "Peel-Tensile Method," described and used by Naugatuck; (c) the "Straight-Tensile Method," described and used by Knowlton Brothers.

These methods are also described in *Tappi* 40: 311–313 (May, 1957), and in *Tappi* 40: 676–680 (Aug., 1957).

A questionnaire has been prepared to be sent to members of the Plastics Committee and those attending committee meetings last February. The purpose of the questionnaire is to solicit expressions on preference and perhaps obtain information on still other test methods for internal bond strength. Hope was expressed that the response to this questionnaire can be reported at the Plastics Committee meeting on February 22.

The selection of a chairman for Project No. 625 was discussed and several candidates were proposed. The chairman will contact them before the next meeting.

V. T. Stannett presented a written proposal for a project on "the Properties of Grafts on Cellulose and Cellulose Derivatives." After a brief discussion it was decided that Dr. Stannett would rewrite the proposal with several changes suggested by the committee members and it would be presented at the February Plastics Committee Meeting for Committee approval.

A general discussion followed on the subject of Research Appropriations and the procedures for committee requests for same.

The committee adjourned for lunch and reconvened at 2:00 p.m.

A general discussion followed on the subject of the 15th Plastics-Paper Conference Program.

W. N. Stickel, *Chairman*

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The rates per issue for Positions Open advertisements in *Tappi* are as follows:

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1/16-page Box	$ 50
1/8-page Box	$ 80
1/4-page Box	$125

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(P981-60)

Verification Problems in Papermaking

CHARLES A. LAMB

MANY fluid-mechanics problems exist in the pulp- and papermaking process. Those of greatest consequence center in the paper machine itself and have a great effect on paper quality as well as the production potential of the machine. Once started, a machine will run continuously for days making rolls of paper from a fiber slurry that has an original consistency of from 0.1 to 1% by weight. Machines differ greatly in design, but have several common functional parts: (1) the filtration of a wet fiber web on a moving fine-mesh screen, (2) mechanical pressing for additional water removal while on, or between, carrying felts, and (3) final drying by means of steam heated driers. Each of the many elements on the machine must function with a high degree of safety to insure that the process does not break down.

The end objective of fluid-mechanics research is to improve the paper quality at a given production rate or to realize greater production at a given quality level. The overall results must, of course, fit into a favorable economic picture. The translation from basic laboratory work to final production application transcends a large number of variables that cannot be evaluated with a good degree of certainty. This has two principal effects on research work. Considerable expense for pilot-plant equipment is justified. It is desirable that such pilot-plant equipment, and model components, be full scale in cross section and in operating speed. Fortunately, the prototype dimensions are such that duplication of cross-sectional scale is quite practical; widths are reduced considerably.

The normal process-development procedure is from laboratory theory and model work, to pilot-plant trials, then to prototype application. The quantity of work done in each phase is a balance between the increased precision that might be obtained and the risk in going to the next stage. It should be pointed out that the sequence of laboratory work, pilot-plant studies, and production application is based on the assumption that the overall objectives and problems in a development are well defined. This is not always true. In some instances, considerable time must be spent on prototype observations and pilot-plant trials, before a constructive overall program can be established.

Perhaps the best way to demonstrate the need for pilot plant components is to discuss briefly some of the more significant development difficulties and then present a specific problem example.

The greatest technical problem lies in the poor knowledge of flow of fiber suspensions. Some references exist for specialized flow conditions, but progress is slow because of the difficulty of making hydraulic measurements. The fibers hang up and agglomerate on the leading edges of measuring elements and small-scale flow-control devices. Visual observations are usually not feasible because of the opacity of the slurries. The problem is complicated further by the tremendous variation in the natural and synthetic fiber furnishes and the mixtures in which they are used.

The fibers also enter into the dynamics of the filtration process. In this case the wire screen, with its partially deposited layer of fibers, is an essential boundary geometry of any flow analysis. Though the drainage relationships for such a boundary are complicated, sufficient data are available for approximate analytical treatments (*1, 2*). The problem differs from the more common porous-flow situations in a number of respects. The web is compressible so that the resistance of a given pad is a function of the total driving force with the concentration of fiber per unit volume increasing throughout its thickness. In a strict sense, the compaction is not instantaneous, nor is it completely reversible. Work to date has been with relatively thick pads; this has yet to be extended to lighter webs where the screen has some effect and a sizable portion of the fiber fines are not retained in the web.

A very important consideration, which is not altogether technical, is how the target of improved paper quality is defined. Uniformity of quality and uniformity of paper weight apply universally to all kinds of paper. Beyond these, each paper can, and usually does, have its own balance of desired qualities that are considered to be of greatest value to the ultimate user. The intangibles of product design, as well as technical problems in process development, strengthen the need for pilot plant equipment.

A last overall consideration has to do with how improvements are applied to production machines. A very large part of increases in paper production is achieved by minimum rebuilds to increase the output of existing machines. Due to differences in vintage, machines are seldom duplicates. Thus, there is a uniqueness factor for each machine that must be considered in all stages from problem definition to possible compromises in final application.

THE WET END OF A FOURDRINIER-TYPE PAPER MACHINE

The particular example to be presented is "spouting," or "stock jump," which can occur on high-speed fourdrinier-type paper machines. In the light of the previous discussion, it should be pointed out that spouting is not a universal problem on all machines of this type nor is its problem aspect well understood. Thus, the following work was done primarily to help achieve a problem definition and point to possible ways of controlling the phenomena.

A typical headbox, or inlet, and fourdrinier section of a book-paper or newsprint machine is shown in Fig. 1 in its simplest form. The widths of modern book-paper machines run to about 20 ft. of newsprint machines to about 30 ft. The length of the flat part of the moving wire, or fourdrinier section, might be up to 65 ft. Speeds of newsprint machines go to over 2000 f.p.m.; speeds for better grade papers are less than this.

The inlet is a pressurized box that delivers a thin jet (about $^1/_2$ in. deep) of dilute pulp slurry across the machine width. The inlet pressure is controlled within narrow limits so that the slurry velocity is substantially the same as the velocity of the endless wire-screen that is rotating around the fourdrinier section. The function of the fourdrinier section is to dewater the slurry from its original consistency of 0.5 to 0.8% to a consistency of about 18%. At 18% solids the fiber web has enough strength to support its own weight over a span of a few inches. Following the fourdrinier, the web is transferred to the press, or felt, section where endless felts carry and protect the web while it is mechanically pressed to consistencies of 35% or so. Steam-heated drum driers complete the drying of the paper.

CHARLES A. LAMB, Kimberly-Clark Corp., Neenah, Wis.

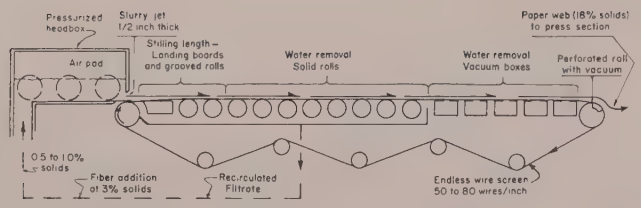
Pressurized headbox
Slurry jet 1/2 inch thick
Stilling length – Landing boards and grooved rolls
Air pad
Water removal Solid rolls
Water removal Vacuum boxes
Paper web (18% solids) to press section
Perforated roll with vacuum
0.5 to 1.0% solids
Fiber addition at 3% solids
Recirculated Filtrate
Endless wire screen 50 to 80 wires/inch

Fig. 1. Section of representative fourdrinier for bookpaper or newsprint machine (distorted horizontal scale)

Machines differ in detail but have three general functional areas on the fourdrinier. The slurry is very free draining when it first lands on the wire screen and no deliberate effort is made to remove a great deal of water. The slurry is allowed a stilling length and the members under the wire are primarily to support the wire and remove free water that has drained to the underside of the wire. The longer middle section of the fourdrinier consists of "table" rolls that pump water out of the sheet; high vacuums exist in the leaving nips of the solid rolls. The water removal capacity of the rolls diminishes as the slurry thickens and a section of slotted stationary vacuum boxes is necessary for the last length of the wire. The slurry loses its wet appearance and becomes nonreflective before leaving the vacuum box area.

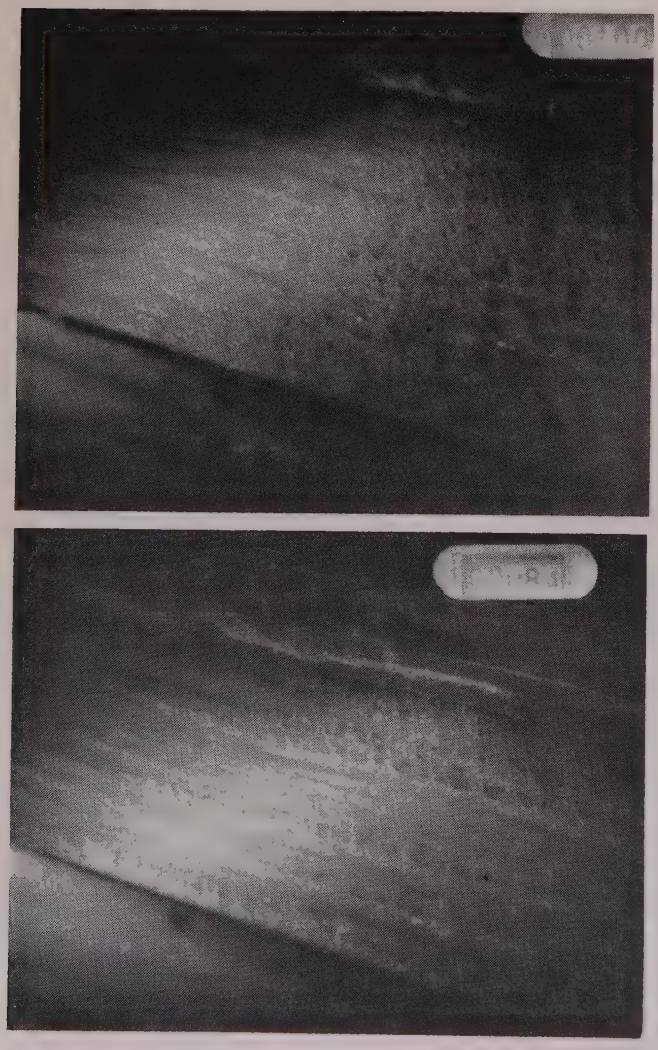

Fig. 2.

(*a*) Spouting after first solid table roll on 19-in. wide experimental unit. Speed of 1500 f.p.m. headbox consistency 0.58% (1 microsecond).

(*b*) Different approach-flow conditions.

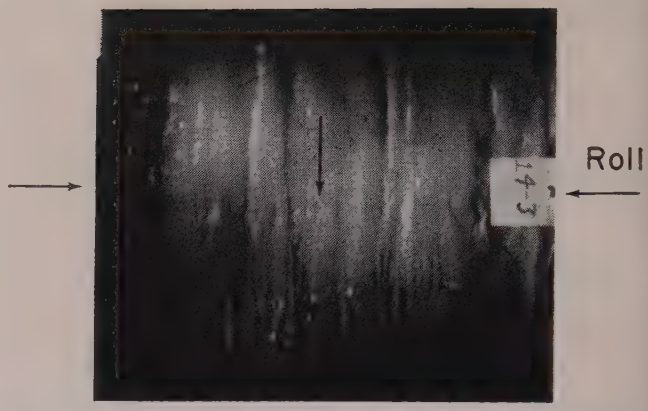

Fig. 3. Photograph of ridges rising from low streaks (3000 frames per sec.), viewed from above

SPOUTING ON THE FOURDRINIER

Figure 2 shows spouting which is occurring after the first solid table roll. This is normally the inception point although it can occur where the slurry jet hits the wire. Unless grooved rolls are very lightly grooved, they will not cause spouting; on the other hand they remove much less water than solid rolls. The differences between Figs 2(a) and 2(b), which show similar setups except for the approach flow, explain in part the inconclusive nature of past work or opinions on the mechanism of spouting.

Many photographs of the phenomena exhibit an inversion pattern of the surface depth. Spouts rise from what were previously low streaks, or spots, in the flow approaching the roll. This pattern is easiest to distinguish when the flow has a predominance of ridges such as shown in Fig. 3.

The suggested mechanism for spouting is shown schematically in Fig. 4. The region of roll wrap causes a growth in the magnitude of nonuniformities; for the sake of simplicity we will again consider them to be primarily of the ridge type. The most appropriate reference for fluid being accelerated away from its free surface is some work by Lewis and Taylor (*3, 4*). They find that the growth of disturbances due to the downward acceleration of the fluid is given by

$$\frac{\eta}{\eta_0} = \cosh \sqrt{\frac{4\pi s}{\lambda} \frac{(g_1 - g)}{g_1} \frac{(\rho_2 - \rho_1)}{(\rho_1 + \rho_2)}}$$

where:

η_0 = amplitude of initial disturbance
λ = wave length of initial disturbance
s = downward displacement of the fluid
g = acceleration of gravity
g_1 = induced acceleration
ρ_1 = density of upper fluid
ρ_2 = density of lower fluid

In the present case, the magnitude of the acceleration ratio is not significant because the acceleration of gravity is small in

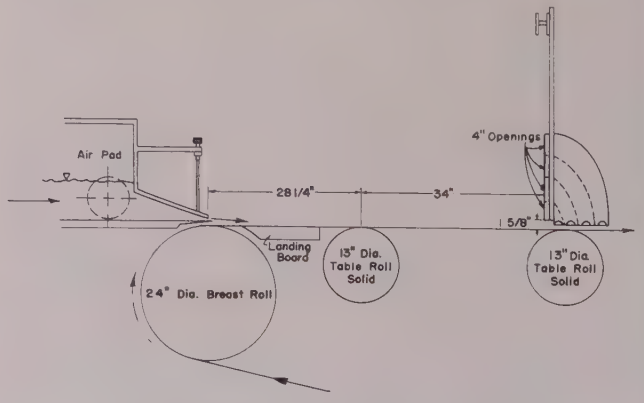

Fig. 4. Diagram of spouting mechanism

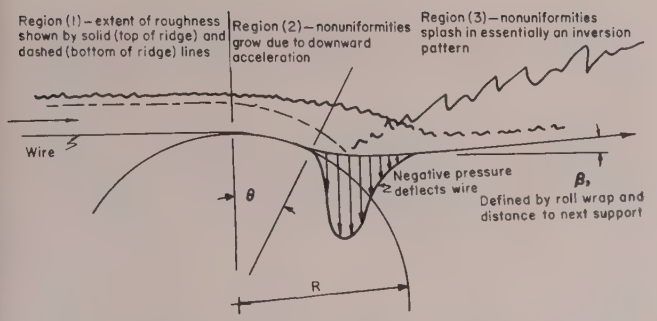
Region (1) – extent of roughness shown by solid (top of ridge) and dashed (bottom of ridge) lines
Region (2) – nonuniformities grow due to downward acceleration
Region (3) – nonuniformities splash in essentially an inversion pattern
Wire
θ
Negative pressure deflects wire
β,
Defined by roll wrap and distance to next support
R

Fig. 5. Diagram of headbox and catch-pan arrangement

comparison to g_1. Densities p_1 and p_2 are fixed with p_1 being negligible. On the basis of this equation, the total downward displacement and the original scale of the disturbance are the only items over which some control might be achieved. As an overall consideration, it is not possible for this region to cause any slurry to rise above its original horizontal trajectory.

If the free surface approaching the point of wire release from the roll were completely smooth, there would be no mechanism for spouting. The impingement of irregularities of flow onto the released wire results in lateral velocity components that in turn collide and cause the spouts, or in simple terms, splash. The inception of spouting could be expected to depend on the angle of impingement, the velocity of the slurry, and the character of the approach flow that has now been modified by the preceding region. The geometry of the wire, which should be indicative of the impingement angle, can be described by considering a free body of the wire over the leaving nip. The upward components of the wire tension forces must be balanced against the pressure integration beneath the wire plus the changes in vertical momentum of the slurry. Taylor (*5*) has published a theoretical basis for determining the pressure distribution in a leaving nip:

$$\text{max. nip vacuum} = {}^1/_2\,\rho V^2$$

$$\text{nip length} \propto {}^1/_2\,\frac{k\rho RV}{\mu} \text{ (at this value nip vacuum is max.)}$$

$$q = {}^1/_2\,(0.590)\,\frac{k^2}{\mu^2}\,R\rho^2 + V^3$$

in which the previously undefined variables are

V = velocity
k = drainage coefficient with a length dimension (higher k means more free draining)
R = roll radius
μ = dynamic viscosity
q = drainage rate

Taylor's work has been substantiated by Burkhard and Wrist's experimental measurements in a practical sense, even though there are some questionable assumptions in the theoretical treatment (*6*). The relationship of Taylor's theory with impingement angle indicates that spout inception would be fostered by increasing speed, increasing roll diameter, decreasing drainage resistance, or decreasing wire tension. The last of these, wire tension effect on spouting, is quite well established.

The theories of the growth of nonuniformity and subsequent splash are both related to the amount of wire deflection. The possible variables that might be controlled to diminish wrap would also diminish the amount of water removal and lengthen the fourdrinier. The following tests were undertaken to verify possible means of control and to explore the mechanics of the two related fluid deflections.

PILOT-PLANT FOURDRINIER TESTS

The principal group of tests were made on a 19 in. wide, experimental fourdrinier section. The section was too short to make finished samples of paper at the sheet weights of present

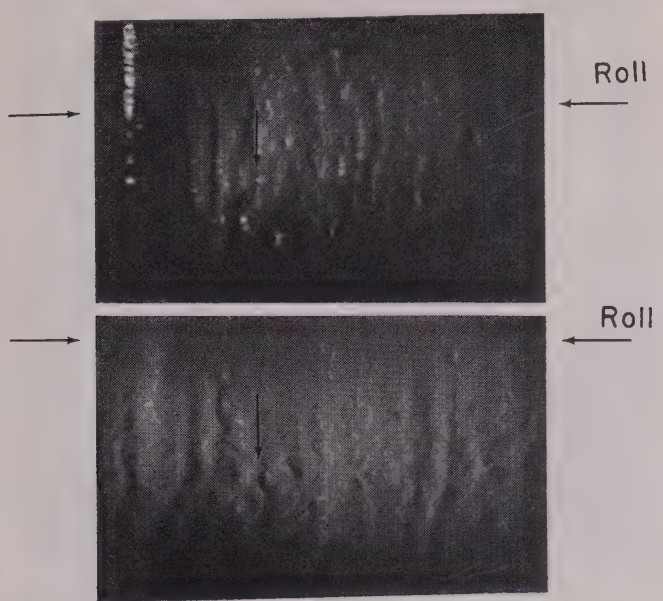

Fig. 6. Photographs of flow on completely sealed wire.
(*a*) Plane wire.
(*b*) Table roll raised to give 2° of wire wrap on roll.

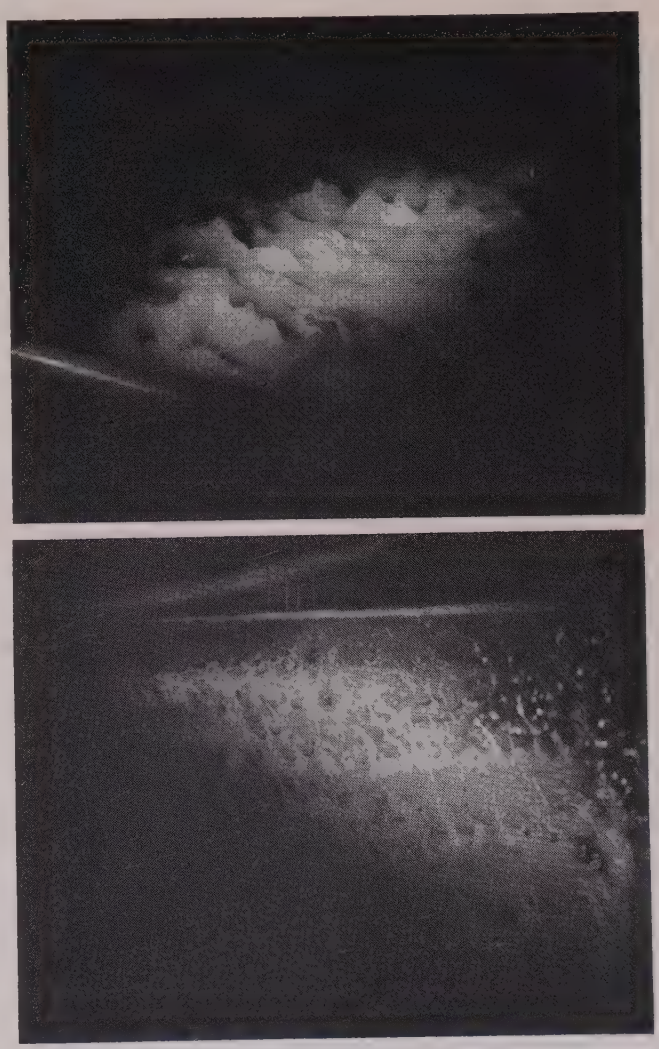

Fig. 7. Comparison of spouting character approximately 18 in. downstream from table roll
(*a*) Growth of nonuniformities with sealed wire. Wire wrap on roll—2°.
(*b*) Normal type spouts.

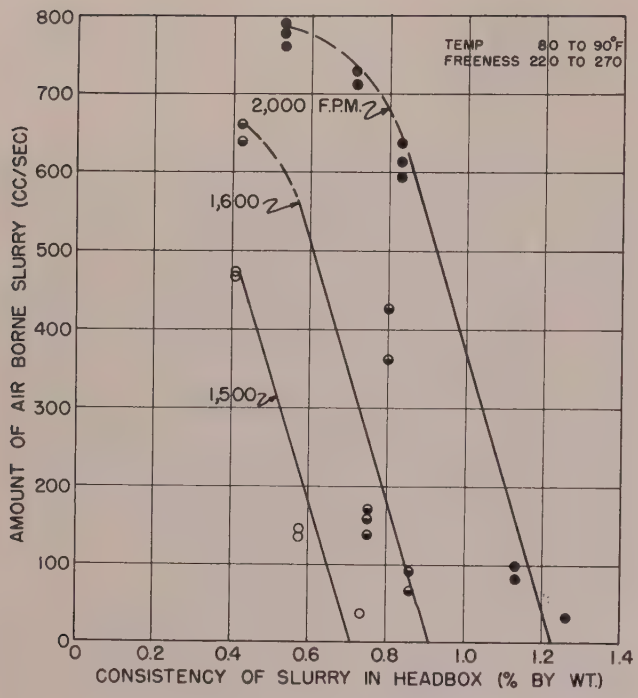

Fig. 8. Quantity of airborne slurry versus consistency of slurry in headbox

interest. The web slurry from the wire was remixed with the filtrate and recirculated to the headbox. The recirculation of the long fraction of the fibers with the fine solids that pass through the wire prevented the selective building of fines that is characteristic of a continuous process. It was felt that this did not seriously affect the relative results of the tests. Tension of the wire was held constant by means of a weighted stretch roll.

The general test layout is shown in Fig. 5. The catch pan was located slightly upstream of the maximum elevation that the airborne slurry would achieve at speeds of 1500 to 2000 f.p.m.

A wire was completely sealed with four coats of Hypalon to check the limiting condition of infinite drainage resistance. The coating was quite flexible and did not materially stiffen the wire. No indication of spouting was observed with the wire running on a flat table. Hosing of large quantities of water into the entering and leaving nips had no noticeable effect on this stable flow condition. The solid table roll was then raised 1 in. which resulted in an artificial roll wrap of approximately 2°. Comparison of these two conditions is shown in Figs. 6(*a*) and 6(*b*). Note that the wrap condition, which corresponds to only the downward acceleration over a normal roll, causes disturbance growth but no signs of an inversion. The scale and character of these nonuniformities are shown in Fig. 7(*a*); Figure 7(*b*) shows normal spouts at approximately the same scale. Some of the higher areas went off in almost a normal trajectory elevation. The immobility of the headbox structure made it impractical to

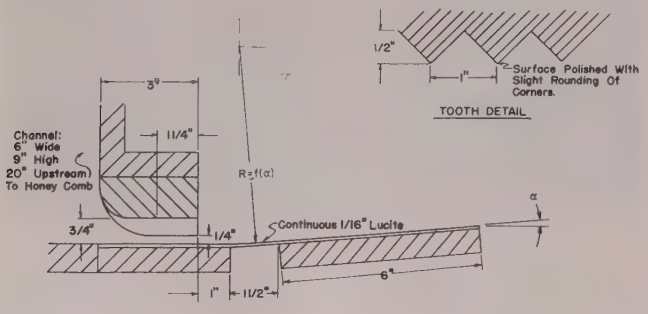

Fig. 9. 6-In. wide jet-deflection flume

maintain similar approach flow conditions on a more steeply sloped wire so further increments of wrap were not tested.

A normal wire was then installed with the table again in its flat position. Runs were made at constant speeds with inlet consistency as the controlled variable. The determinations of airborne slurry resulted in the curves shown in Fig. 8. The 4-in. increments of the catch-pan opening were too coarse to give a significant distribution of the airborne fractions. No measurable slurry was obtained in even the second opening until the 500-cc.-per.-sec. level was reached. One hundred cubic centimeters per second is equal to approximately 0.25% of the headbox discharge. Each increment of 0.1% increase in inlet consistency had a quieting effect on the jump equivalent to about 100 f.p.m. drop in speed.

The effect of roll diameter was investigated by replacing the 13-in. roll with a 5-in. one. The 5-in. roll gave no measurable jump within the speed range previously investigated with consistencies to less than half a per cent. The slurry immediately downstream of the roll was observed to be quite "wild," however.

SMALL-SCALE MODEL TESTS

It was not possible to isolate the impingement aspect of spouts on the test fourdrinier. This was done in a qualitative way by utilizing a simple jet-deflection flow section shown in Fig. 9. The top profile piece was selected on the basis of its simplicity as well as the fact that it is somewhat representative

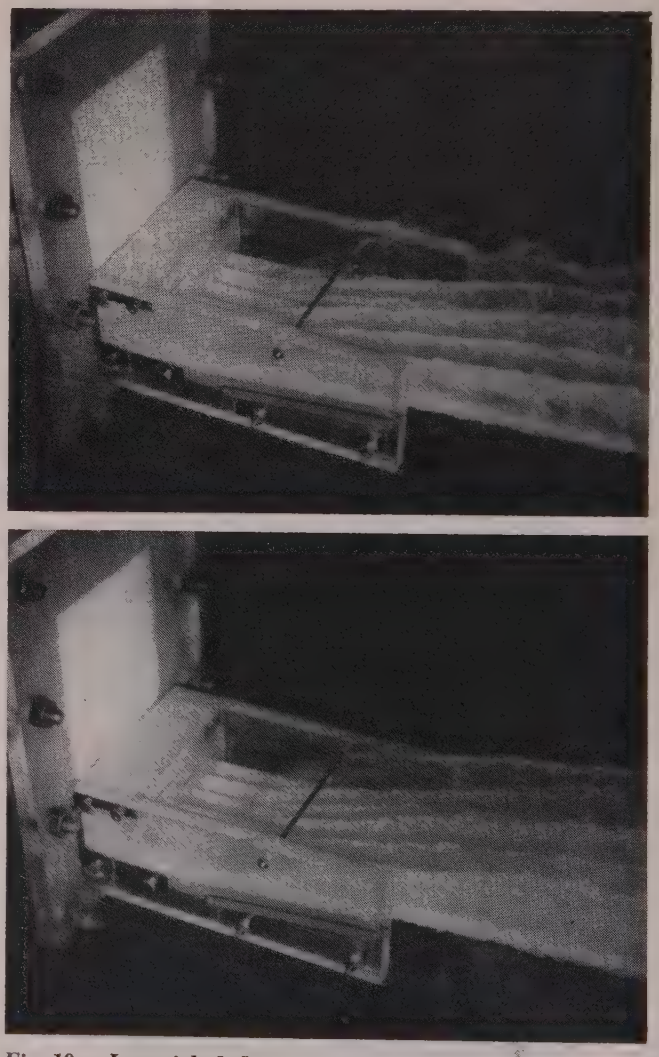

Fig. 10. Jets with deflection angle of 6°50′ (1 microsecond exposure; 0.04% coating-clay solids added for flow visualization)

(*a*) 1500 f.p.m.
(*b*) 2500 f.p.m.

of the flow approaching the end of the roll wrap. The 1-in. spacing of the teeth was of the same order of magnitude as some of the ridges observed in the earlier trials. The section was made quite close-coupled to minimize possible boundary-layer and edge effects. No separation was observed in the contraction, although some disturbance may have resulted from the three-dimensional flaring of the curve.

The splash of the jet with an impingement angle of 6°50′ is shown in Figs. 10(*a*) and 10(*b*). (This angle is of the proper order of magnitude for our wrap considerations.) Several measurements were made for this condition. The quantity of water rising in the spouts was determined by holding a scoop down to the bottom of the spout at a point 1 in. from the end of the lucite section. The results are shown in Fig. 11. Spout (b) was less symmetrical than the others. The rise angle of the spouts was determined from photographs. This angle was 9°37′ relative to the 6-in. bottom piece at 1500 f.p.m. and 10°33′ at 2500 f.p.m.

Downward deflection of the jet is shown in Fig. 12. At any downward angle the deflection of the top of the ridges was quite minor.

ENERGY DISSIPATION IN SPOUTING

An important consideration in spouting is the possible energy loss that may result from the mechanism. The tests on the 6-in. flow section, with its simplified ridges, suggested a mechanism of energy exchange without an immediate consideration of internal losses in the slurry. A net loss in forward momentum of the slurry can occur even if the internal losses over the roll and through the splash are negligible. The energy, hence velocity, of the fluid can be constant, but the impingement of the ridges will result in part of the flow having significant lateral velocity components. The net loss in machine-direction momentum could be computed if the flow after impingement could be described in detail. The fourdrinier wire must then supply the energy necessary to bring the slurry back up to wire speed.

Momentum losses can be computed from practical measurements, if one more step is taken. The quantity and upward velocity of the airborne slurry is the same as the lateral velocity pattern if the lateral flows collide with no internal losses, negligible surface tension restraint, and in a symmetrical manner. The rise angles in the 6-in. flow section indicate that the rising fluid has lost 1.7% of its horizontal velocity component at 2500 f.p.m. The horsepower necessary to bring the airborne portion back to wire speed would be 0.005 hp. per ft. of width at 1500 f.p.m. and 0.022 hp. at 2500 f.p.m. (this assumes all of the fluid is rising at the same angle). Values for the pilot plant test can be computed by using the maximum elevation of the spout trajectories. At the 600-cc.-per-sec. airborne-slurry level and 2000-f.p.m. screen speed, a portion of the slurry had risen 6 in. and lost 1.5% of its horizontal velocity.

INTERPRETATION OF RESULTS

The regions of nonuniformity growth and splash will be discussed separately before considering their composite. The tests to attempt a separation of the two occurrences were directed primarily at spouting after solid table rolls, but they are of more general application to instability on the fourdrinier. For example, the rebound aspect can occur as an isolated case, if the jet from the headbox strikes the wire at too steep an angle.

Growth of nonuniformities in a region of downward acceleration is perhaps an understatement. Some of the higher nonuniformities had very little downward deflection when observed on the sealed wire test with 2° of artificial wrap. Normal roll wrap at these speeds would be about three times this value (*6*). This was also substantiated through the observations on the 6-in. flow section. The limited degree of flow deflection explains the second pressure peak of Burkhard and Wrist's pressure profile measurements (*6*) through a roll nip.

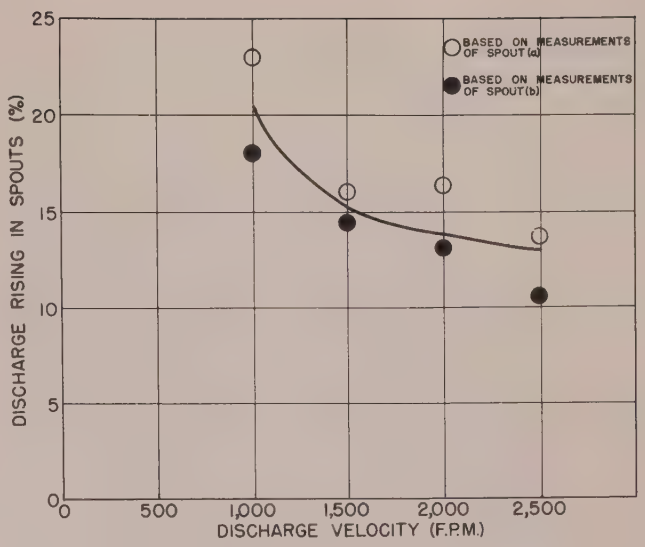

Fig. 11. Discharge rising in spouts versus velocity—6°50′ deflection angle

As the fluid becomes more loosely associated with the bottom surface, it causes less vacuum due to centrifugal force.

An isolated splash could be obtained only in the 6-in. flow section. By necessity the approach flow was an idealized pattern being somewhat representative of true scale only in two dimensions. The rise angles of the splash and the fractions of airborne water were found to be quite constant in the 1500 to 2500 f.p.m. range for a given impingement angle. This indicates that internal losses, surface tension, and gravity are of relatively minor importance. This conclusion should not be extrapolated to slurry on the wire without further studies. Fiber content in the fluid could cause a damping effect on the splash. Investigation of this aspect would have required additional refinements to the 6-in. flow section and measuring means. A comparison of the surface smoothness between the two cases showed appreciable differences; the approach flow in the 6-in. section had a very fine scale surface roughness.

It is difficult to give any experimental proof that the airborne fraction of the liquid has a lower velocity component in the horizontal direction than the rest of the flow. The original argument was that the maximum efficiency of the splash would be one of constant energy. Since this occurred with a change in direction, part of the momentum in the direction of the flow has been lost. (This is not quite like the case of a jet impinging on a flat surface since some force is created at the curvature point.)

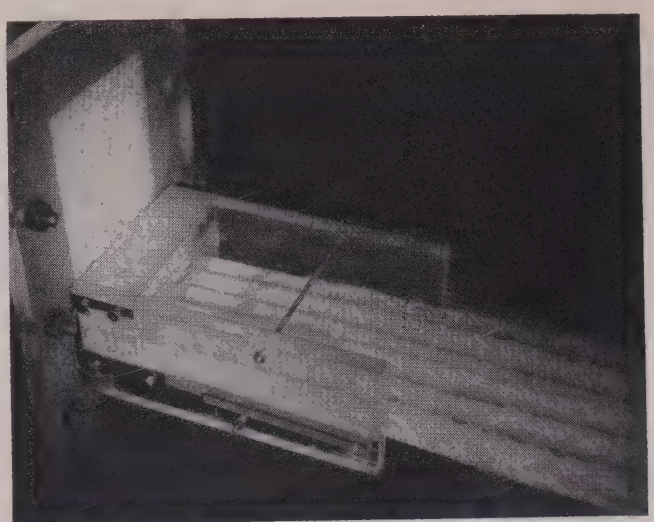

Fig. 12. Jet with deflection of 3° below level

The backward lean of spouts and splash nonuniformities would support the velocity picture if one could say that each came from the same source. This is probably true but was not verified in detail. Air drag would also retard the air-borne liquid. Rough estimates of air drag indicated significant, but not major, effects.

A lengthy discussion of energy dissipation, or exchange, due to splash would be nebulous. The values presented here could greatly underestimate true magnitudes because of the assumptions that were necessary to facilitate calculations. The only quantity that can be given a specific significance is the loss in machine-direction velocity of the air-borne liquid. This portion of the slurry will exert a drag when it returns to the wire—a drag that can be compared with the control tolerance on the slurry discharging from the headbox. The control limits on the discharge from the headbox may be as low as $\pm 1/2\%$ for better grade papers; if the difference between slurry and wire speed is greater than this the paper suffers in quality. A good share of the airborne slurry is out of these control limits and could affect paper quality for this reason.

Movies and still photographs of flow over solid table rolls exhibited the distinct regions of nonuniformity growth and subsequent splash quite well. It was more apparent in low areas than for higher ridges. Higher ridges would frequently carry farther downstream from the roll; this might be expected because of the limited downward deflection of ridges. Air bubbles in the slurry are excellent inception points for spouts, but their population was not sufficient to have any significance in these tests. None of the observations indicated that the surface condition was being governed by flow in the entering or leaving nips right under the wire (*5*).

The tests of different roll sizes, drainage resistance, and headbox consistency behaved as predicted; that is, conditions that gave more water removal were also more conducive to spouting. Unfortunately, this does not allow much latitude in reducing spouting on present machines.

Roll diameters and wire tensions are dictated by structural considerations. The slurry composition and the wire resistance are dictated primarily by product design; so these items, with their effect on drainage resistance, cannot be used as a control means. The problem is one of compromising the necessary water removal against inception or magnitude of spouting. The amount of water to be removed can be diminished by increasing the fiber consistency in the headbox slurry, but this has adverse effects on paper quality after a certain level is reached.

Work to establish the relationship of approach flow to spouting could result in significant design improvements. Many machine limitations that are attributed to spouting could be due to the fact that a poor flow condition from the headbox is being exaggerated by spouting or is, perhaps, causing it. A technical background of this aspect would do much to determine where and how much money should be spent to upgrade a machine.

On a longer-range basis, it would be well to consider the general aspects of free-surface stabilities rather than just the solid table rolls. Other types of drainage elements have higher incipient spouting speeds, but all result in some degree of wire deflection.

The course of the previous discussion emphasized most of the general problems presented in the introduction. The phenomenon of spouting, which can be described quite simply, was shown to involve many unknown relationships. A precise knowledge of each would require a great deal more research work. A minor number of pilot plant tests made it possible to define these areas and also produced a framework of knowledge that was adequate for suggesting several development programs.

The translation of the problem to paper quality was not supported by specific results because of limitations to the pilot-plant fourdrinier length. Furthermore, such evaluation would be quite specialized and beyond the intent of this paper.

CONCLUSIONS

Pilot-plant equipment, which is essentially full scale in cross section and speed is highly desirable for papermaking process development. The problem of spouting on the fourdrinier demonstrated how such equipment defines technical problems for laboratory study and at the same time facilitates a semi-empirical approach to development work.

Spouting was found to be best described as a splash resulting from nonuniform flow impinging on the wire. Inception of spouting was found to be largely dependent on geometric conditions. Additional work is needed to verify whether internal resistance, surface tension, and gravity restraint are negligible at higher machine speeds.

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The writer wishes to acknowledge the help of the many people who participated in the various aspects of this work. Particular acknowledgment is due W. F. Morgan for his experimental determinations, the Photographic and Chart Departments for the illustrations, and to C. A. Lee whose efforts are largely responsible for the existence of the experimental equipment. Acknowledgment is made to the management of Kimberly-Clark for releasing this material for publication.

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Questions and Answers

Good engineering questions are solicited as well as answers or alternate answers to the published questions. Material should be sent to TAPPI Headquarters, marked for the attention of H. O. Teeple. The items contributed will be forwarded to the Question and Answer Committee for processing. If comments are to be contributed, please refer to the question number.

*(48) *Question* (**Wattmeters Require Adjustment**): **On one of the feeders going out from our plant the voltage is stepped up from 2300 to 13,200 and, at the end of a 5-mile transmission line, stepped down again to 2300 v. Power is metered on the 2300-v. side of the transformers at both ends of the line. Should not both meters register the same? As it is now, the meter at the out end of the line registers considerably more than the one at the power plant.**

(*48.2*) *Answer:* In my opinion, answer 48.1 is only slightly related to the question. Since feeder metered on 2300-v. side of transformers, and assuming no load taken from 13200-v. transmission line, the power metered at out end of line should read less than that at power plant end by amount of losses in both banks of transformers and

Note: Questions and answers marked with an asterisk (*) are reproduced courtesy *Power* magazine.

transmission line. Error could be one of connections, CT or PT ratio for the particular meters, error in meters.

H. B. Barrow,
General Electric Co.,
Atlanta, Ga.

(1-4/60) *Question:* **What does the committee feel is the best material for use as a grout and mortar for installing carbon brick?**

(*1.1–4/60*) *Answer:* For carbon brick linings in alkaline pulp digesters, the best material now available for use as a grout and mortar is portland cement with a properly selected aggregate. The choice of aggregate depends upon the particular service conditions. The aggregate must be inert under the chemical conditions involved and these, of course, vary depending upon whether the process is kraft, soda, semichemical, or other. As an example, the quartz or silica-type aggregate is no longer specified in the case of kraft cooking, whereas this type of aggregate may still be suitable for certain semichemical operations. Certain types of feldspars, dolomitic limestones, and other minerals can be specified but in each case the exact operating conditions must be known and the minerals must be obtained from specific locations and must have been previously tested.

In answer to the second question, some service histories can be given. It is possible to cite carbon brick linings in hardwood digesters which have been in service for 15 years or more which have required little or no maintenance during that period and which allowed no liquor to contact the steel shell.

(2-4/60) *Question:* **To what extent does the tension in a pickup felt influence its useful life? Is the use of high tension detrimental to long life, or is the major factor the abrasion of the felt by slippage at the driven rolls as the felt changes tension and therefore stretch, around the roll? I am assuming that the operators have correctly adjusted the various roll speeds to avoid slippage caused by a real speed difference between the felts and the rolls."**

Peter Wrist,
The Mead Corp.,
Chillicothe, Ohio

(*2.1–4/60*) *Answer:* First of all, in our opinion, the felt must be run under a tension that is sufficient to make the felt lay flat on the machine, run without wrinkles, operate the guide and not pucker or creep as the felt enters or leaves each succeeding nip. We believe this tension is somewhere between 8 and 15 lb. per lineal inch. We do not know how critical this tension is. We are inclined to believe from our observations that the tension is not critical, providing it does not exceed some maximum figure which will differ for various types of felts having different warp constructions. This figure could be in the range of 20 to 25 lb. per in., or even more, depending on the amount and kind of warp. If the warp is too weak or lacks resilience, this figure would be low; if the warp is stronger and has high resilience, this figure would be higher. From practical observations a felt which was being run too tight would be a felt that would continually slack off and have to be retightened.

In our opinion the major factor in the weaving of suction transfer pickup felts is the friction and abrasion that is caused by the motion between the driving rolls and the felt. This relative motion is probably the result of roll surface deformation at the nip. Almost all of the felts that we look at in our laboratory are worn on the roll side rather than on the sheet side. There is no doubt that some internal wear or attrition goes on. This, of course, is the thing that we have looked at and have attempted to study in these power balance experiments. Unquestionably, there is some point at which the stretch in the felt between individual units is so great that the felt literally "rubs itself to death internally." We find on examination of returned felts that some show a relatively large drop in original warp strength as compared with others.

There are a number of factors that influence this such as microbiological attack and chemical damage, but in many cases we have been able to isolate the cause as excessive changes in tension to which the felt has been subjected in its path around the machine. I don't think that because the operators correctly adjust the various roll speeds to avoid slippage caused by a real speed difference between the felts and the rolls that we can assume there is no slippage or motion. Our observation of used felts from all machines convinces us that there must be some motion or slippage no matter how correctly the speeds are adjusted.

It is a fact that most felts are not worn out uniformly in the strict sense of the term. They are rather worn out in streaks or random holes appear, or the felts are removed from the machine for other reasons such as filling up. Actually, we believe that a certain very small amount of motion within the felt, in other words, a changing tension around the machine, is a definite plus factor as far as keeping the felt clean. The power balance studies are important because they enable us to put some numbers on the amount of power being transmitted. While our observations have shown us that the felt is quite tolerant of large differences in the amount of power transmission in most cases without startling effects on the life of the felt, we feel that more and more studies of this type will enable us to draw more precise limits on tension and power transmission. We have the means of putting numbers on felt tension with the portable Huyck-Meter and with various felt length measuring devices. It would be a good idea for any mill that is transmitting some power through a felt as you are in a suction pickup felt to take periodic measurements of the change in tension or change in length of the felt around its path and calculate the amount of power transmitted by the felt.

I. H. Peters,
Huyck Felt Co.,
Rensselaer, N. Y.

(3-4/60) *Question:* **"How do cyclic temperatures affect a stainless steel welded overlay lining?" Digesters are normally charged about five times a day, and during this process, a temperature change of about 160 °F. is made in a short period of time.**

J. T. Firestone,
Everett Kraft Mill,
Pulp Div.,
Weyerhaeuser Timber Co.,
Everett, Wash.

(*3.1-4/60*) *Answer:* There has been no evidence so far that cyclic temperature and pressure changes have had any effect on stainless steel overlays which were properly installed. Some overlays have been in for 8 to 9 years and show no signs of attack or cracking. It is possible that some fissuring which has shown up has been aggravated by cyclic stresses.

(4-4/60) *Question:* **It is our opinion that titanium coated 310 electrodes provide a smoother surface, better interlocking of beads and more freedom from cracks and slag inclusions. Are we correct in this assumption?**

(*4.1-4/60*) *Answer:* Titania coated 310 S.S. electrodes would normally give a smoother weld bead surface than lime coated, depending on the welding technique employed. There is no reason to believe that the weld deposit would be freer from inclusions. In some positions the more fluid titania slag might have greater tendency to become trapped. The titania coated electrode deposits were considered, in the past, to have greater crack sensitivity than lime coated.

(**5-4/60**) *Question:* **Automatic overlay is much faster and, in most cases, cheaper by the square foot basis than manual overlay. However, automatic overlay produces decidedly more dilution which in some cases, runs as high as 60%. From analysis made of manual overlay, dilution is usually in the range of 20 to 30%. If the welds in both cases are sound, will the per cent dilution be an indication of service life?**

(*5.1-4/60*) *Answer:* It is expected that the greater weld dilution, either in manual arc or automatic overlay, will reduce service life due to lowering of the alloy content in the deposit.

(**6-4/60**) *Question:* **Is it not possible to make up overlay samples using different techniques and rod analysis and subject these to accelerated tests for the purpose of determining what constitutes the best overlay for digester service?**

F. D. Whitehead, Jr.,
West Virginia Pulp & Paper Co.,
Covington, Va.

(*6.1-4/60*) *Answer:* Overlay test samples have been made up for testing under digester service conditions. These tests do not truly represent the cyclic stress conditions that an overlay installation would be subject to. They also do not provide an accelerated service life test. An attempt has been made to accelerate corrosion by subjecting the overlay coupons to anodic etching in kraft cooking liquors. The results were not conclusive.

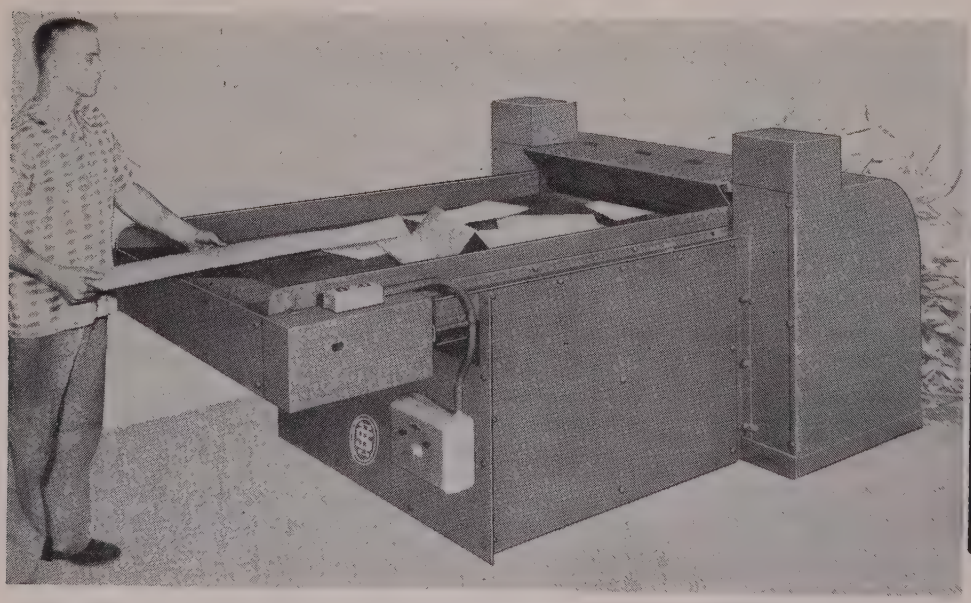
(**7-4/60**) *Question:* **We have heard of corrosion problems, particularly with stainless steel overlays in other mills. The writer feels that we have no trouble with the stainless overlay because we first corrected the corrosion problem on the mild steel parent metal. Our recovery system does not employ smelters or ash quenching systems and we apparently keep in our system a required amount of corrosion inhibitors. This, plus the addition of elemental sulfur, seems to protect our vessels adequately.**

J. H. Crist,
West Virginia Pulp & Paper Co.,
Tyrone, Pa.

(*7.1-4/60*) *Answer:* Every possible effort should be made to prevent corrosion in alkaline pulping digesters. The work done by R. B. Kesler of The Institute of Paper Chemistry on the effect of certain chemicals in cooking liquor indicates that reductions in corrosion rates are possible. If corrosion rates are reduced, there will be no need for overlay or for corrosion resistant linings.

(**8-4/60**) *Question:* **Minimum thickness of stainless steel overlay required and why?**

(*8.1-4/60*) *Answer:* It has been suggested that the minimum thickness of weld metal overlay should be $^1/_8$ in. This is the minimum thickness at the thinnest point. It is necessary to provide sure coverage with a minimum amount of dilution with carbon steel base metal.



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26 St. Louis Section, Le Chateau, St. Louis, Mo. Charter Presentation.
28 Delaware Valley Section, Engineers Club, Philadelphia, Pa., E. J. Albert Award Program.
28–30 Pacific Section, Bellingham, Wash., Annual Meeting.

May, 1960

3 Berkshire District—New England Section, Wendell Sherwood Hotel, Pittsfield, Mass.
3 Chicago Section, Chicago Bar Association, 29 S. LaSalle St., Chicago, Ill.
10 Golden Gate Section, Hotel Claremont, Berkeley, Calif., True Memorial Lecture and Charter Presentation.
12 Empire State Section—Northern District, Annual Ladies' Night.
12 Kalamazoo Valley Section, Harris Hotel, Kalamazoo, Mich., Recognition Night, WMU Awards.
12 Ohio Section, Hartwell Country Club, Cincinnati, Ohio, Ladies Night.
13 Empire State Section—Metropolitan District, Ladies' Night.
13 Gulf Coast Section, Jung Hotel, New Orleans, La.
17 Ohio Section—Indiana District, Marott Hotel, Indianapolis, Ind., "Testing." Speaker: Arthur Dreshfield, The Glidden Co.
20–21 Virginia-Carolina Section, Wilmington, N. C., mill visit to Riegel Paper Corp., Acme, N. C.
20–21 Southeastern Section, General Ogelthorpe Hotel, Savannah, Ga.
21 Empire State Section—Eastern District, Annual Ladies' Night.
27 Delaware Valley Section, Beloit Eastern, Downingtown, Pa., Tour and Outing.
27 Lake Erie Section, Annual Outing and Ladies' Night.

June, 1960

3–4 New England Section, Chatham Bars Inn, Chatham, Mass., Spring Meeting.
10–11 Empire State Section, Whiteface Inn, Whiteface, N. Y., Annual Meeting.
17–18 Maine-New Hampshire Section, Mountain View House, Whitefield, N. H., Annual Meeting.
21 Kalamazoo Valley Section, Annual Golf Outing, Gull Lake Country Club.

September, 1960

21 Pacific Section, Salem, Ore., "Modernization."

October, 1960

7–8 New England Section, joint meeting with Connecticut Valley PIMA, Schine Inn, Chicopee, Mass.

December, 1960

5 New England Section, Storrowtown Tavern, West Springfield, Mass.

April, 1961

10 New England Section, Storrowtown Tavern, West Springfield, Mass., Management Night.

Chicago

A brief summary of the December meeting of the Chicago Section of TAPPI is presented below.

There was an excellent turnout for the December 1st meeting with 150 persons in attendance. Subject covered was "Implications of the Recent Food Additives Amendment as It Applies to Food Packaging." The speaker was John H. Guill, Jr., chief, Chicago District of Food and Drug Administration.

Mr. Guill gave a brief history of the FDA; how, in the early years, many quite toxic materials were marketed with serious consequences. Following several such experiences, Congress enacted Federal regulations and departments working on such regulations gradually evolved into U. S. Department of Health, Education, and Welfare.

John H. Guill

The food additives amendment of November, 1958, was the latest modification to the control of materials used in packaging which contacts foodstuffs. Specific comments and explanations were presented by Mr. Guill. The information was quite new to many in the audience, and was instructive to all in attendance. [*Tappi* 43, No. 3: 160A (March 1960).]

February, 1960

Following is a brief summary of the February 2 meeting of the Chicago Section of TAPPI.

The general title was "The Coming Age of Webfed Offset Printing." There were five speakers with W. D. Hall acting as moderator. James Metcalf of American Type Founders Co., Inc., presented a series of slides showing the types of presses in use as well as folders and sheeters used with the presses.

Left to right: Robert Lee, Andrew Monroe, Clark Snyder, James Metcalf, Herbert Asten, and William D. Hall

Herb Asten of the Cottrell Co. discussed in more detail the various types of presses, also giving information as to types of driers used with webfed presses.

Andrew Monroe of Hess & Barket made comparisons of webfed to other types of printing, and included discussion as to quality, cost, and limitations of webfed offset in relation to other methods.

Clark Snyder of George Hantsche Co., Inc., covered possible application to boxboard and in general the problems connected with printing different types of board finishes. He indicated that waste was rather high running 8 to 15% depending on runs.

Robert Lee of Bowers Printing Ink Co. discussed the ink problems connected with web offset printing. Rub and scratch resistance might be a problem in the packaging field, but he felt this and other problems could be solved.

MELVIN H. MEYER

Web Offset—An Evaluation

H. A. Asten

I HAVE been asked to say a few words tonight about a method of reproduction that has certainly come in for its share of "romancing" in recent months—web offset. Undoubtedly, there is a great future for the web offset process. In the years to come, the number of installations will grow and the quality and quantity of production improve.

But in order to start off on the right foot, let me assure you that the growing volume and variety of printing indicates there is enough work for all the processes. No one method of reproduction is going to completely capture the market. Web offset has many advantages, but to realistically evaluate them it is necessary to understand the operation of the various types of machines, their potentials, and their limitations.

BASIC DESIGN

There are basically two types of web offset presses. One is a blanket-to-blanket design, and the other a blanket-to-steel design. The blanket-to-blanket design can be considered in two primary categories according to their cylinder arrangements—the vertical and the horizontal.

The vertical arrangement, possibly the best known, has the cylinders arranged, top to bottom, like this: plate cylinder, blanket cylinder, blanket cylinder, and plate cylinder.

This is a perfecting operation, both sides of a web being printed simultaneously, with each blanket cylinder acting as the impression cylinder for the other unit. A machine of this type may be composed of any number of units and utilize multiple web operations, such as running one web in four colors or two webs in two colors, on a four-unit machine.

The *horizontal type* of arrangement of the blanket-to-blanket design has the cylinders laid out in a horizontal rather than a vertical plane. For example, reading from left to right, the unit would be composed of a plate cylinder, blanket cylinder, blanket cylinder, and plate cylinder.

The same principles are involved as in the vertical arrangement, but there is a loss of flexibility in the way the webs can be run. This horizontal arrangement, one of the first web offset designs, has recently appeared again on a press one manufacturer is offering for weekly suburban newspaper application.

The blanket-to-steel type of design can be considered in three main categories. There include what we call an inline arrangement, a common drum, and a split drum.

The *inline cylinder arrangement* is very similar to the arrangement in a sheet fed offset press. From top to bottom, there is a plate cylinder, a blanket cylinder, and an impression cylinder.

In this arrangement, the web passes between the blanket cylinder and the impression cylinder, printing one or more collors—depending on the number of units—on one side of the sheet. The application is primarily for such things as labels, gift wraps, etc., where only one side of the sheet is printed before it is folded, sheeted, or rewound.

The *common drum* principle has been most frequently used on high-speed magazine letterpresses. In a web offset design, this is a single, common impression cylinder surrounded by any number of colors for one-side printing. For example, a four-color machine would have four printing units, consisting of blanket cylinder and plate cylinder arranged around the common impression cylinder.

As as example of application, a 50-in. machine of this design would print four colors on one side of the web, and then pass over a drier and into a similar printing unit to back up the sheet with another four colors. Or, common practice with this type of machine would be to use it as a double-ender. In other words, instead of a 50-in. web, a 25-in. web could be run through on one side of the cylinder, printing and drying four colors. The web would then pass through bay windows to turn it over and be led back through the other side of the same common drum and backed-up with the same four colors. This means the press is printing only half its rated web width but it is printing both sides using only one printing unit.

The *split drum* is a variation of the common drum. In this design, two common impression cylinders—each with two printing units—are arranged in a horizontal plane. The web wraps these two impression cylinders at one time, obtaining the same degree of wrap, or contact, it would with a common drum.

The principle is the same as the common drum, but the design provides greater accessibility, so important for fast make-ready. An example of this design is the eight-color Harris-Cottrell web offset press we have operating in Poughkeepsie, N. Y. The crew on this press consistently strip and lay eight plates and are up to color and register in a little over an hour. This doesn't include changing paper or ink. Even so, I believe you will agree this is a very fast get-away. So much for the types of presses.

TENSION CONTROL

One of the most important functions in a web offset press is the maintenance of proper tension control, since accuracy of register is so very much dependent on it. Tension control starts with the white unprinted roll as it is fed into the press.

Roll feeds fall into two categories—the standard-type roll stand offered by most manufacturers, particularly in the small size presses, and the multiple-roll stands equipped with automatic flying pasters. The web tension is generally controlled by a core brake PIV type of arrangement or a running belt.

The core brake PIV type applies a braking force directly to the shaft on which the core is mounted. Pressure is applied or taken off as required. The web is then fed in through a pyramid arrangement of rolls with a PIV type of drive to control tension.

The running belt tension control consists of two 10-in. wide running belts which actually drive the roll of paper and feed it into the printing unit. A weight directly opposite the pneumatic cylinders assures proper tension throughout the roll, taking into account its reduction in weight and circumference.

The automatic paster is made by several different concerns, and is usually used with triple-roll stands. One roll is running, one is being prepared for the pasting operation, and a third roll is in readiness to swing into a pasting position. At a time determined by the operator, or by an electric eye, a new roll is spliced onto the depleted roll, on-the-run.

H. A. ASTEN, Manager—Web Offset Sales, The Cottrell Co. (a subsidiary of Harris-Intertype Corp.).

LITHOGRAPHIC UNITS

The blanket and plate lockups on the web lithe unit are somewhat similar in design to sheet-fed press, but since the web offset press, like any web press, has a fixed cutoff, it is highly desirable to obtain as much printing area as possible. Consequently, the plate cylinder gap is very small as compared to a sheet-fed machine.

The plate is generally bent on a fixture so that it registers with the other plates when it is snapped into the internal locking system on the cylinder. It may be necessary to move the cylinder laterally or circumferentially to bring it into exact register. This can generally be done while the press is running. However, cocking of the plate is not a common practice in web offset because of the high hourly cost of the presses and the ability of the bending fixture to produce an accurate bond in the plate.

The blanket cylinder lockup is very much like a sheet-fed machine but is done internally with respect to the cylinder. This permits a narrower gap, generally about a half inch. Because it is necessary to fit two thicknesses of approximately 0.065-in. blankets into a slot in the cylinder, it seems unlikely that this nonprinting area can be reduced much more. With these methods of locking on the plate and blanket, make-ready time is usually faster than on a sheet-fed press of the same size.

As mentioned before, the arrangement of the lithographing units can be either blanket-to-blanket or blanket-to-steel, depending on the job to be accomplished and the type of press the buyer favors.

The inking and dampening systems are also similar to a sheet fed machine. The arrangements, their settings and adjustments, all closely resemble the sheet-feds but because of the higher web speeds the units are more ruggedly constructed. However, we all believe that better methods are needed in both of these areas to produce the best quality at the speeds we expect to obtain. Our company, for example, has at least three different forms of dampening systems under test in the field.

DRYING

After the web has been printed, it must go through a drier if we are to take advantage of the high speeds of the web offset press. Heat-set inks are used as in high-speed magazine presses. There are three basic types of drying equipment.

The steam drum drier has been most prominent in the letterpress magazine machines, where one side printing is generally performed. After one side has been printed, the web wraps the steam drum (wet side out), and is dried. The web is then backed up on another pristing couple and the same procedure followed on a second steam drum.

This type of drier has not been too common in the web offset field because the majority of the machines are of the blanket-to-blanket perfector type which produces a web printed both sides and would require one wet side of the web to be in contact with the steam drum.

Ordinarily, the drier on a web offset press is one which carries the web straight through and dries it by either electric or gas heat. The most common of these is the gas fired drier which drys both sides of the web as it passes through.

After the web is dried, it is then passed over a series of two or three chill rolls. These are rolls filled with circulating cold water which absorb the heat which has been applied to the web by the drier and restores its original temperature before it passes into the folder. Here again, since tension is such an important factor in register, these chill rolls must be driven at a precise speed so they work in conjunction with the feed-in devices, or the roll stand, to maintain proper tension throughout the run.

TERMINAL OPERATION

The terminal operation of the web offset press can be a rewind, sheeter, or folder. A rewind operation is generally used for one side printing and/or where the web will eventually be sheeted. Although the sheeting can be accomplished on the press, it usually makes it necessary to run the press at a slower speed. With a rewind, high speeds can be realized with, perhaps, more than one sheeter used to cut the printed web into individual flat sheets.

The most common terminal operation is, of course, a folder. I believe that one of the great advantages of the web offset press is lost if a folding operation is not involved. With the use of a folder, a roll of paper can be converted into a printed, folded, finished, or semifinished product in one operation. It is even possible for the job to be pasted, stitched, and trimmed if that is the requirement. Some folders, today, have provisions for doing all these operations. At any rate, much handling is eliminated when a folded product is produced.

Folders fall into many categories, and you frequently hear the terms such as former, jaw, chop, and so forth.

A former is a triangular shaped metal board, generally chrome plated and perforated for air. The web passes over this board and is formed into a fold at the nose. This is the type commonly used on newspaper presses, and many high-speed magazine machines.

A jaw fold is just what it sounds like. A cylinder acting as a jaw has the paper tucked into it by a tucker blade in another cylinder. Two of these in the same plane produce a parallel fold.

A chop fold, sometimes referred to as a quarterfold, is what sheet fed people would term a right-angle fold. This is generally accomplished with either a vertical or a rotary action of a blade putting a cross or right angle fold into a signature as it comes through the folder.

Most folders are able to produce a lap, or lip as some refer to it, for the gathering machines. Folders may also be collect or noncollect. As an example, one might deliver two 16-page signatures, noncollect, or one 32-page signature, collect. The web is also sometimes slit into ribbons, and each ribbon put over individual turner bars to bring them in line with each other and form various paging combinations. At times, these turner bars are reversible so that each ribbon can be flopped to change paging around to various positions of the signature.

CONCLUSIONS

In summation, let us not forget that the primary disadvantage of web offset—in fact all web presses—is the fired cutoff. This means, for instance, that on a web press with a $22^{3}/_{4}$ in. circumference, or cutoff, every sheet that passes through must be $22^{3}/_{4}$ in. In other words, if you have a job that requires only $21^{3}/_{4}$ in. paper around the cylinder, you are wasting 1 in. or approximately 5% of the paper for every revolution. This is a sharp contrast with the flexibility of a sheet-fed press.

The initial cost of the installation of any web press is high in comparison to sheet-fed machines. This, however, is in line with the fact that such a press is capable of turning out a very high volume of work. And, due to the high initial cost, which results in a relatively higher hourly operating cost, a considerable backlog of work would be required to utilize such a press economically.

On the other side of the ledger, let us examine some of the advantages of web offset today. Where a folded product is required, in-line web production, by eliminating many individual operations, offers tremendous savings in handling alone. Also it is possible to handle a wider range of stock than on a sheet-fed machine because you are not concerned with the tail-end fan-out of the sheet, or transfer of the sheet. One of the more limiting factors in running some stocks on a sheet-fed press is the separating mechanism. This, of course, is not a problem on a web fed machine.

We have positive proof that the reproduction of a dot on a web fed press is as good as on a sheet-fed press. Some

companies have already proved to customers' satisfaction that the quality of web fed offset can equal that of sheet-fed. We know from experience in the sheet-fed field that we run better at higher speeds and we have longer plate life with less water and fewer stops. These conditions are enhanced by the very nature of a web offset operation. While the cost of paper in rolls is less than buying in flat sheets, generally the waste is higher so that one will pretty well balance out the other.

Of course, the big factor in web offset is the higher production. Some of the things possible are quite breathtaking. As an example, a five-unit machine in a 35 by 50-in. size with a rated speed of 1200 f.p.m. could be run with one web in one-color and one web in four-colors, split into ribbons, interleaved at the folder, and produce four–15's, two–32's, or a 64-page signature with black and four color process interleaved (or run-of-book color) at the rate of 25,000 per hr.

The future outlook of web offset is bright indeed. There is much engineering and research work being done to improve the dampening and inking systems. We at the Cottrell Co. feel that without a doubt our greatest potential growth is in the web offset field.

Presented at the meeting of the Chicago Section of TAPPI, held in Chicago, Ill., Feb. 2, 1960.

Web-Offset Application to Board Printing

Clark Snyder

Assuming you gentlemen are here this evening for reasons other than good fellowship and a chance to meet with your competitors to determine whether or not their problems are any worse than yours, let us face the fact for a moment that competition, mounting manufacturing costs, and the usual unreasonable demands by our customers no doubt is sending you out to find new, faster, and less expensive methods of producing higher quality work than you have been able to produce in the past.

As representatives of a leading web offset press manufacturer, we have been approached by people in the boxboard printing business, and have been quoting on presses. We've had a pretty good opportunity to hear some of the problems of printed boxboard. Only to a few of these manufacturers does the web fed offset press have any real application, though it has an appeal to almost all of them—the advantage of close register, four-color process halftones, or color work, and above all, the rapid plate preparation, the speed from original copy to printing plate, with which many of you are familiar who are printing boxboard on sheet fed offset presses. These are not the only advantages shared by both sheet fed and web fed, but this and the ability to print on rough, uncalendered surfaces.

Web fed offset presses have many clear advantages over sheet fed, in that there is a better control of color quality throughout the run, once the press is adjusted for register and ink flow. It has a speed, operating at speeds—roll-to-roll or roll-to-sheet—very near that of rotogravure, faster than the new high-speed die-cutters.

Both the sheet fed and web fed press share the same difficulty of picking up lint on the blanket, from boxboard, transferring it to the image in the plate and lowering the quality of the job. Equipment is made that rather successfully removes any loose lint from the surface of rough boxboard, at least that loose material which may tend to coat the blanket. This is another step ahead in overcoming some of the inherent difficulties in gaining good quality.

The web fed offset press is not the complete answer for the boxboard printer's problem because he wants a web fed machine that will be adjustable to suit the repeat, or the length of the die in the die cutter. Because these presses must be designed with a minimum of three cylinders, the offset press does not lend itself to interchangeable cylinder arrangement, or cylinders of various diameters, like letterpress or rotogravure presses.

Rather unfortunate experiences have come to those who have attempted to build web fed offset presses with interchangeable cylinders to meet the requirements of variable repeats. This narrows the usefulness of the web offset press to a few of the great number of jobs which will fit a cylinder repeat on these offset presses with the least amount of waste.

The web fed offset press has appeal over rotogravure machines in other ways. A lot of valuable time is lost waiting for rotogravure cylinders to be ready for mounting on the press. During this time a web fed offset press, because of faster plate preparation, would have a sizable quantity of material on its way to the customer. This would mean a lot when the customer is making an all-out effort to combat a good campaign launched by his competitor. Another avenue of appeal will afford the customer an opportunity to experiment in package designs or short-run campaigns to better market his product without going to the cost of a more expensive printing media; printing syndicated packages with a common background and local individuality is becoming usual, especially today, as employed publishers of syndicated premium catalogs.

One of the manufacturers of playing cards has been running highly calendered stock, a 12-pt. board, four colors on two sides of the web and sheeting, for a good number of years. They have been so pleased with the results that they have ordered additional equipment to increase their production. Playing card runs are not all long runs, as both the fronts and backs are changed, from time to time. Press speeds of about 1200 f.p.m. produces the equivalent of 30,000 decks per hour. Register marks are die cut out of the web in the press, which, of course, have to be die-cut and packaged. Not only do these people produce the cards on this press but they also produce some playing card boxes, on 20-pt. board, as this press, a perfecting press, can be used for printing on one side of the sheet only, if need be.

Highly calendered stock or coated board poses some problems in boxboard printing because the inks do not soak into the surface of the paper as well as they do on unfinished boxboard. When running coated, calendered stocks, it is necessary to include an oven to liberate the vehicle and dry the sheet so the ink can be set, as the web travels over chill rolls—after the folder—these are large drums through which water is circulated to maintain a lower temperature. When printing a soft or porous boxboard, any reasonable number of colors can be applied without the danger of serious scuffing or smearing before the web is cut or re-wound.

Offset has another advantage over other printing methods—it is probably the only process by which it is possible to print solids and fine screen halftones on a rough board. The pressure between the blanket and the board to be printed is enough to print every bit of the exposed surface without damage to the stock. This, of course, does *not* apply to corrugated board.

I've tried only to skim across some of the high points in boxboard printing by way of offset. I'd rather not clutter up this time with a bunch of random information when some of you will probably have specific questions you'd like to have answered.

Presented at the meeting of the Chicago Section of TAPPI, held in Chicago, Ill., Feb. 2, 1960.

Clark Snyder, George Hantsche Co., Inc., Chicago, Ill.

Pulp Bleaching Conference
Sponsored by
TAPPI
Edgewater Beach Hotel
Chicago, Ill.
June 14–16, 1960

Ink in Relation to Web Offset

Robert Lee

To KNOW ink problems in web offset we must understand how heatset inks differ from oxidizing inks. Drying of heatset inks is accomplished by release, in the oven, of a volatile solvent from the vehicle, this causes polymerization of the ink, which is equivalent to the drying action we know in oxidizing type inks. As the sheet leaves the oven the ink is gummy, the final set on the ink is accomplished by chill rollers.

Heatset solvents are available to various ranges of flash points. Flash point of a solvent determines at what degree drying starts, and also affects the stability of an ink on the rollers. A lower flash point makes for a more unstable ink. In packaging you will have a thought on odor-free inks, deodorized solvents are available.

Pigments are comparable with those used in the inks you are now using, although scratch and rub resistance could be a problem in the packaging field, inasmuch as heatset vehicles contain a percentage of solvent which is completely released, leaving a smaller percentage of resin in which to incorporate rub and scratch resistant qualities.

I am sure that when the packaging industry gets into web offset, your inkmakers will be able to handle problems as they arise, and do the same job for you they have done in the past.

Empire State (Eastern District)

The November meeting of the Eastern District of TAPPI was held at the Queensbury Hotel with 49 members and guests in attendance.

Chairman Paul Page called the meeting to order at 8:30.

Bill Montgomery gave the treasurer's report showing a checking balance of $145.64 and a reserve fund of $527.60 making a total of $673.34.

Chairman Paul Page anounced that a roster of members for the Eastern District will be compiled shortly and John McCoy will take the dues of the new members present.

Harold Lake, chairman of the Junior Awards, reported that he was almost certain of four persons to present their papers and that his goal is 10. The contest is open to anyone under 35 years of age.

The chairman informed the group that the next meeting was to be a panel discussion on "Dyes and Dyestuffs." Participants are as follows:

Grant Cole, Finch Pruyn & Co.—Continuous Dye Addition System.
John Martinovitch, American Woodboard Co.—Pigment Addition to Cylinder Board.
Fred Sunstrom, American Cyanamid Co.—Factors Governing Color on Machines.
H. Lake, C.I.B.A.—Concept of Color.
M. Landberge, General Aniline & Film Co.—To be announced.
Dr. Earl Johnson, Moderator.

Ray Wiles of the International Paper Co. introduced the guest speaker Dr. S. G. Mason, Head of the Physical Chemistry Division of the Pulp and Paper Research Institute of Canada. His topic was "The Behavior of Pulp Fibers in Suspension."

January, 1960

The January meeting of the District of Empire State TAPPI was opened by Chairman Paul Page, at the Queensbury Hotel, Glen Falls, N. Y., with 72 members and guests present.

Mr. Page gave a résumé of the first three meetings and what is to take place at the future meetings.

Gordon Nicholson, vice-chairman, reported on the progress for the April symposium on "Wet End Machine Operation."

The Publicity and Membership chairman John McCoy made a plea for members to submit their autobiographies.

James Fusco, the Education chairman, will report next month on the current high school program.

Grant Cole reported that the raw materials list is quite complete and that requests for some of the materials have been received.

Earl Johnson the third vice-president of the Empire State Section in charge of the Junior Awards for the Empire State was introduced to members and quests.

The Program Chairman Gordon Rabeler introduced the quest speaker, Kenneth Simpson of Arthur D. Little, Inc. Mr. Simpson spoke on "Operation Research in the Paper Industry."

Mr. Simpson discussed how scientific analysis can be applied to management decisions and gave a history of the field dating back to its origin during World War II.

An interesting question-and-answer period followed.

V. W. POTTS, *Secretary*

Empire State (Northern District)

Present at the meeting of the Northern District of the Empire State Local Section of TAPPI, held at the Hotel Woodruff, were, left to right: Russell C. Clark, chairman, H. Dyer Phillips, James W. Field, national representative, Prof. Frank W. Lorey, State University College of Forestry, Syracuse, Charles B. Blanchard, and John L. Hudson, Jr.

Education in Pulp and Paper Technology

F. W. Lorey

THE College of Forestry offers instruction in several fields relating to forestry and forest products. Different curricula available include forest management, forest biology, and landscape architecture relating to biological sciences, and wood products engineering, forest chemistry, and pulp and paper technology relating to physical sciences. The curriculum in pulp and paper technology has little to do with the general conception of forestry. The pulp and paper student is interested in the use rather than in the growing of wood and as such is concerned with the physical and chemical properties of wood rather than silvicultural methods.

The paper industry in the United States is an industrial giant. In 1958, 30,797,000 tons of paper were produced in the United States and 35,285,992 tons consumed, with the difference between production and consumption being mostly newsprint imported from Canada. When dividing the con-

ROBERT LEE, Bowers Printing Ink Co., Chicago, Ill.

F. W. LOREY, State University College of Forestry, at Syracuse University, Syracuse 10, N. Y.

sumption by average population in 1958 (about 173.8 million people) one finds that the average consumption per capita for that year was 405.4 lb. This is compared to 365 lb. per capita in 1948, 244 in 1939, and 220 in 1929. Thus, not only must the paper industry expand to keep up with the yearly population increase (about 3 million people), but also to meet increased needs of paper due to new products. Although population increase has been less than 2% a year, paper industry expansion during the last 20 years has been 3.2% a year, and during the next 5 years domestic production is expected to increase at a rate better than 5% a year. Opportunities for work in the paper industry are extremely good, since a shortage of technical personnel exists at present, and this shortage will continue to exist in the foreseable future.

The paper industry also has shown great stability, and does not reflect the violent peaks and valleys in business conditions as do some other industries. During the depression of the early 1930's employment in all industries declined 36% whereas paper employment declined only 20%. The recession of 1957–58 saw many industries operating at 60% of capacity whereas the paper industry as a whole operated at better than 80% of capacity.

The paper mills in the Watertown area are quite diversified and offer the student an excellent opportunity to become better acquainted with the paper industry. Due to the shortage of wood, this region no longer has the national significance that it had 35 years ago, although New York state still ranks fourth among the states in paper production and this locality is a major papermaking region of the state. Practically every type of paper is made in this area including board, printing grades, fine papers, tissue, kraft papers, industrial papers, saturated papers, and molded pulp products, just to name a few. Large tonnage items such as newsprint and containerboard products, based on abundant wood supply are the exceptions. From viewing the operations of St. Regis at Deferiet, one can become familiar with practically every type of operation found in the industry, namely, wood room operation, mechanical pulping, chemical pulping (except recovery), pulp bleaching, paper machine operation, paper coating, supercalendering, and finishing room operation. Thus, the opportunity to become better acquainted with this rapidly expanding industry is right here for the asking.

The pulp and paper industry is thriving in many sections of the country other than New York State. Paper is made in 42 of the 50 states, with mills centered in the Northeast, Lake States, South, and Northwest. Opportunities for employment and advancement are available in all of these regions.

The undergraduate curriculum in pulp and paper technology at the College of Forestry consists of a thorough foundation in chemistry, mathematics, and physics, followed by a comprehensive coverage of the chemistry and engineering aspects of the processes used in the pulp and paper industry. The first three years of the curriculum are concerned mostly with science and mathematics courses, along with such courses as English composition, economics, and public speaking, while the fourth year is concerned with the detailed study of the chemistry of wood and its conversion into pulp and paper. In addition, employment for at least one summer in a paper mill is required, along with a detailed report of the mill's operations.

Presented at the meeting of the Northern District of the Empire State Section of TAPPI, held in Watertown, N. Y.

The film presented, "From Wood Fibers to Paper," is the story of the program in pulp and paper technology at the College of Forestry. It was produced by William M. Harlow, and is available for loan throughout the country free of charge by addressing Extension Department, State University College of Forestry at Syracuse University, Syracuse 10, N. Y.

February, 1960

Paul E. Grunder, technical sales representative, Dow Corning Corp., presented a film entitled, "You and the Silicones," and spoke about specific applications of silicones in the pulp and paper industry at the February 11 meeting of the Northern District, Empire State Section, TAPPI, held at the Hotel Woodruff, Watertown, N. Y.

Empire State (Metropolitan District)

Dewaxing of Waxed Paper Broke by Adsorption

A. P. Allegrini and A. W. Claxton

An economical and feasible process for reclaiming fiber from waxed paper broke has been developed by Minerals & Chemicals Corp. of America. Fiber containing less than 1% wax and polyethylene was reclaimed from wax coated and impregnated paper and board, such as, food containers, kitchen wax paper, paper cups, bread and bubble gum wrappers. Evaluation of handsheets prepared with dewaxed fibers indicate that the dewaxing treatment had no adverse effect upon their physical properties.

The process consisted of four basic steps, namely: (1) shredding the broke to a size which would not entangle in the subsequent stages; (2) heating the broke in the presence of granular adsorbent such as Attapulgus clay; (3) separating the fiber from the adsorbent; and (4) regenerating the clay by heating at 1000°F. to restore its adsorptive power.

The process has been successful in a continuous pilot plant operation utilizing a paper shredder, a rotary steam tube drier for dewaxing, a sifter and a direct-fired rotary kiln for regeneration. This equipment can be scaled-up to plant size. Direct operating costs excluding overhead, amortization and overhead for reclaiming fiber at the rate of 25 tons per day (24 hr.) from a broke containing 28 to 30% wax were estimated at less than $9.00 per ton.

EXPERIMENTAL

The first series of experiments were carried out in laboratory batch apparatus. A 12 in. diam., 15 in. long hollow steel cylinder equipped with lifting flights and revolving at 10 r.p.m. along a horizontal axis was used for dewaxing. The clay-wax broke mixture was heated in the cylinder by gas flames impinging on the exterior surface. The clay was separated from the fiber by sifting over a 4-mesh screen. A smaller cylinder of similar design was utilized for clay regeneration.

The pilot plant equipment included:

1. A swing type hammer mill for shredding. This was the only type of equipment available to us at the time. A conventional paper shredder, however, is recommended.
2. A 1-ft. diam., 8-ft. long continuous steam tube rotary drier for dewaxing.
3. A 4-mesh screen.
4. A 1-ft. diam., 10-ft. long continuous refractory lined, counterflow, direct gas-fired rotary kiln.

DISCUSSION OF RESULTS

The dewaxing capacities of the clay adsorbents for reclaiming wax coated and impregnated paper brokes are illustrated by the data in Table I. Granular size adsorbents, such as, +30 mesh −60 mesh were found to be better suited than −325 mesh powdered clay because of lower adsorbent losses and better handling characteristics. Polyethylene was also removed effectively from the various brokes.

The degree of dewaxing increased with clay loading, contact time and temperature as indicated by the results in Table II. The temperature has to be maintained at a safe

A. P. Allegrini and A. W. Claxton, Minerals & Chemicals Corp. of America, Research Division, Menlo Park, N. J.

Table I. Dewaxing of Various Coated and Impregnated Waxed Paper Brokes with Clay Adsorbents

Broke	Before dewaxing: Wax content %	Before dewaxing: Polyethylene %	Clay loading, parts clay/part broke wt. basis	Temp., °F.	Time, min.	Dewaxed fiber: Wax content, %	Dewaxed fiber: Polyethylene content, %
Solid bleached waxed carton	8	..	3/1	2W0	20	0.67	..
Waxed paper (frozen food overwrap)	25.0	..	2/1	250	10	0.52	..
Kitchen waxed paper	21.0	..	3/1	250	10	0.40	..
Waxed bread wrapper	27.0	..	10/1	240	20	0.40	..
Waxed paper broke	26.0	2.00	20/1	240	20	0.87	0.28
Waxed paper cups	5.3	1.00	20/1	250	20	0.04	0.12
Waxed paper bubble gum wrapper	18.5	6.4	20/1	265	17	0.72	0.14

level so as to prevent charring or destruction of fiber strength.

The data in Table III showed that the clay could be used for three treatments before the wax content of the fiber exceeded 1%. However, the clay life was prolonged by heating at 1000°F. to expel the adsorbed carbonaceous constituents as illustrated in Table III. A small percentage of clay estimated at 0.3% would be lost during regeneration. This is caused by the degradation of granules into fines which are carried away by the combustion gases during regeneration.

The waxed paper broke required shredding to a size such as 2 by 2 in. or smaller which would not cause tangling in the various processing stages.

Table II. The Effects of Clay Loading, Temperature, and Contact Time on the Dewaxing Capacity

Dewaxing of kitchen waxed paper broke original wax content: 20–21%

Adsorbent	Clay loading, parts clay/part broke wt. basis	Contact time, min.	Temp., °F.	Wax content of dewaxed fiber
Attapulgus clay				
20/40 mesh	2/1	10	250	1.19
20/40 mesh	3/1	20	250	0.40
20/40 mesh	5/1	10	250	0.16

The summarized operating and performance data obtained in the continuous pilot plant equipment are shown in Table IV.

For a plant size operation the waxed paper broke would be shredded using a conventional knife cutter, then pneumatically conveyed to a surge or storage bin. Granular 30/60 mesh adsorbent consisting of new "makeup" clay, regenerated clay, and possibly partially spent clay would be fed at metered

Table III. Life of the 30/60 Mesh Unregenerated Clay Adsorbent for Dewaxing Waxed Paper Broke Containing 20.0% Wax Using 3 Parts Adsorbent Per Part of Broke

No Regeneration

Wax content of paper broke, %	←	20–21%		→
Adsorbent/waxed broke ratio	←	3/1		→
Temperature, °F.	←	250–260		→
Contact time, min.	←	20		→
Times adsorbent used	1	2	3	4
Wax content, %				
Dewaxed fiber	0.61	0.51	0.89	2.46
Adsorbent	3.9	6.3	10.7	12.4

Regeneration

The dewaxing properties of the regenerated[a] 30/60 mesh

Attapulgus clay adsorbent	3 Parts clay/part waxed broke, 250°F./20 min.: Wax content of waxed broke, %	3 Parts clay/part waxed broke, 250°F./20 min.: Wax content dewaxed fiber, %
First use	20–21	0.10
After first regeneration	20–21	0.27
After second regeneration	20–21	0.28
After sixth regeneration	20–21	0.35

[a] Regenerated by heating at 1000°F. for 30 minutes.

rates to the steam tube drier together with the broke. The adsorbent loading, the contact time in the drier and the temperature would depend on the nature of the broke and the dewaxing demand. The products from the drier would be screened over a vibrating or shaking sifter to separate the fiber from the partially spent clay. At this stage a certain

Table IV. Pilot Plant Dewaxing of Waxed Paper Broke in a 1 Ft. Diam., 8 Ft. Long Steam Tube Drier

Waxed paper broke charge	
Wax content, %	18.5
Polyethylene content, %	6.4
Charge to steam tube drier, lb./hr.	
Waxed paper broke	6
New 30/60 mesh clay	40
Partially spent clay	80
Clay loading—parts clay/part broke	20/1
Temperature, °F.	
Steam inlet	350
Product	260–265
Average time in drier, min.	17
Dewaxed fiber	
Wax content, %	0.7
Polyethylene content, %	0.1

portion of the partially spent clay could probably be recycled to the system and the remainder regenerated in the direct-fired kiln. The portion to be regenerated would depend on the dewaxing demand. The partially spent clay and the

Table V. Estimated Operating, Equipment and Installation Costs for Dewaxing Waxed Paper Broke to Produce 25 Tons per Day of Reclaimed Fiber

Estimated direct operating costs, less overhead, amortization, initial clay charge	8.57/ per ton reclaimed fiber
Initial clay charge	48,000 lb. ($1440)
Daily clay consumption	1056 lb.

regenerated product would be conveyed to separate clay bins. The "makeup" clay needed to compensate for the clay losses would be charged to the regenerated clay bins.

Presented at the meeting of the Metropolitan District of the Empire State Section of TAPPI, held in New York, N. Y., Dec. 8, 1959.

Forest Biology Symposium

Sponsored by TAPPI

New Washington Hotel,

Seattle, Wash.,

Aug. 24–26, 1960

Some Special Problems in the Use of Reclaimed Paper Fibers

D. B. Geffkin

THE reclamation of paperboard that has been laminated with cellophane, glassine, saran, or similar materials and the reuse of paperboard that has been coated or extruded with plastics such as vinyl copolymers or polyethylene presents some difficult problems.

The Sealright Co. enjoys a most enviable reputation in the field of moist food packaging. This reputation has accompanied the Sealright name for more than 40 years since the inception of the company activities in paperboard conversion in 1917. Sales in 1959 will exceed 50 million dollars, largely because of the increased use of Sealright products in the packaging of moist foods. The increased sales volume of the Sealright Co. stems from the successful marketing of attractively decorated paper containers equipped with a protective film such as cellophane, glassine, or saran, or plastic coatings such as vinyl copolymers or polyethylene which are designed for moist food applications.

In 1959, the Sealright Co. will consume in excess of 90,000 tons of paperboard. During the first 11 months of 1959, Sealright converting plants located in Los Angeles, Calif., Kansas City, Kan., Peterborough, Ont., and Fulton, N. Y., transferred to the paper mill at Fulton their converting plant waste fiber. This waste must be reused or the present profit structure of the corporation would be reduced. There can be no doubt in anyone's mind that to us the reuse of plastic coated fiber is an absolute necessity.

Paper mill procedures for the repulping of laminated waste have not changed much in the last 15 years. Laminated waste is charged into a 14 ft. hydrapulper and repulped without the use of chemicals. Saran and cellophane materials are stripped from the paperboard and will pass through the pulper extraction plates if the quantity is not excessive, otherwise the extraction plates become sealed off and prevent transfer of the disintegrated stock to the pump. Saran film used in window covers is the most objectionable material that we use. Cellophane is next in degree of objection. Glassine will break up sufficiently to permit extraction. It has been our experience that a furnish consisting of 20% of saran type wastes will cause trouble is used regularly.

Recently we were in a mill producing a lined grade of board for Sealright from raw materials that we supplied. This mill was equipped with a 20-ft. continuous hydrapulper which handled laminated waste much more satisfactorily than the batch type pulper. Much of the laminated material became entwined on the rope and was removed. However, the continuous pulper will not solve the problem completely. Evidence indicated that extraction through the $^3/_8$-in. holes was seriously slowed down after two days of operation.

Other mills have probably experienced some of these problems. I have seen small orange peel buckets hooked up above pulpers to accelerate the removal of nonfibrous materials from the pulper when it is empty. Other mills have to send men into the empty pulper to remove the waste by hand.

From the standpoint of furnish costs the more widespread use of laminated paperboard has caused furnish costs to increase. It used to be possible to prepare liner stock from certain high grades of wastes. Liner furnishes prepared from laminated wastes cannot be tolerated because of the presence of shiners.

Turning attention to a newer problem, the reclamation of plastic coated fiber is more difficult and costly. The Sealright plastic coated milk bottle and food container is ten years old. The product was developed, manufacturing equipment installed and waste was generated. Our paper mill had to perfect a satisfactory fiber recovery process. To our knowledge, no one else was attempting to reprocess this type waste. So we perfected a successful method to handle vinylite coated board. M. R. Kinne has described the system in an article entitled "A System for Reclaiming Vinyl Coated Fiber" which appeared in *Tappi* 39, No. 8: 168A–169A (Aug., 1956).

The recovery of this material does not involve deinking. The inks are alkali resistant and chlorine resistant. Our results are obtained by mechanical methods alone. Now, to mention a few of the problems:

1. The stock would not disintegrate in the regular hydrapulper.

2. A new type pulper having a 400-hp motor was purchased to disintegrate the stock (5000-lb. batch).

3. Hot water (160°F.) was necessary to insure satisfactory separation of plastic from fiber. Water temperatures of 140°F. produced excessive splintering of the plastic film.

4. The high percentage of plastic made screening difficult. We resorted to series screening on Jonsson screens followed by a Vibrotor equipped with 10-out plates. Capacity of the equipment is minimized by the excessive quantity of rejects.

5. Demands for a stock of higher quality required centrifugal cleaning.

6. Striving for a product of maximum purity and a system that will permit greater production, experiments are now under way using a Centriscreen. Initial results indicate that cleanliness will be improved. We are now trying to determine the best location for the Centriscreen.

7. The presence of unscreened plastic particles sometimes makes it difficult to produce a hard sized sheet.

8. Small particles of printed plastic in the filler require up to 0.006 of liner to satisfactorily cover and thus push furnish costs higher and at the same time reduce the quantity of filler stock that can be consumed.

9. Equipment required to process these types of waste is expensive ($300,000 for a 35 ton per day recovery plant). But an additional 35 ton per day can be processed with an expenditure of an additional $85,000.

Plastic coated solid bleached grades formerly used for liner must be processed to remove the plastic. Carloads of unprinted plastic coated solid bleached grades sold to other mills who intended to use the waste for top liner stock discovered that the plastic coating rendered the material unsuitable for liner and have rejected the entire shipment.

A more recent problem that has challenged us is the increased use of wet-strength resins in paper. The combination of neoprene and wet strength resists alkali, acid, and alum. We have not been able to repulp the waste satisfactorily. Recently, we purhcased a high-speed Sprout Waldron hammer mill which when equipped with a $^1/_8$-in. perforated plate produces a very fine fluff that somewhat resembles groundwood in quality. This fiber does not wet out easily.

We have found that we can incorporate about 4% of this stock in the furnish of 0.014 to 0.017 sheets and up to 20% in sheets from 0.020 to 0.040 thick.

The latest problem that confronts us is the reuse of polyethylene coated or extruded board. We have found that the hydrabeater does not do a good job disintegrating polyethylene because its action is too violent. We are presently installing equipment which we believe will enable us to satisfactorily process polyethylene waste. Briefly, we intend to cut the waste into small pieces approximately 3 or 4 in. square and pulp the stock in the hydrapulper using water at 180°F. Temperature of 210°F. would be desirable but difficult to attain and operate. In this respect, TAPPI Monograph No. 16, Deinking of Wastepaper, may contain helpful information.

This talk has been necessarily abbreviated and presented somewhat in outline form. We do not claim to have the best solution for this important problem, but we do salvage

D. B. GEFFKIN, Sealright-Oswego Falls Corp., Fulton, N. Y.

important raw material which is costly to replace and has such a forceful effect on the finished price of our product and the profits of the company.

Presented at the meeting of the Metropolitan District of the Empire State Section, held in New York, N. Y., Dec. 8, 1959.

Italian

Meeting of the officers of Italian TAPPI Section was held at the Italian TAPPI head office, Corso Matteotti 8, Turin, on Feb. 16, 1960, at 10:30.

Present:

Piero Bersano	Alessandro Restagno
Giorgio Cerio	Leto Ridi
Pietro Ghisoni	Giuseppe Villa
Vittorio Gilberti	

The following gentlemen also attended the meeting:

Edoardo Cirla	Carlo Ruspa
Carlo Gregotti	

who are members of the 1959 Executive Committee.

AGENDA

Designation of local section officers; appointment of the Executive Committee; program for 1960 and TAPPI publications; 1960 Conference of the Study Group of European TAPPI Members; National meeting or poplar and fast growth softwood; financial situation.

The committee designated the local section officers by appointing: Piero Bersano as chairman; Pietro Ghisoni and Leto Ridi as vice-chairmen; Alessandro Restagno as secretary-treasurer.

The 1959 Executive Committee was selected again for 1960 and will include the following gentlemen: Edoardo Cirla, Carlo Gregotti, and Carlo Ruspa.

Mr. Bersano stated that all TAPPI local sections are urged to hold elections at the end of March; therefore to include the Italian Section in the normal TAPPI year, the officers resolved that the next elections should take place in March, 1961.

As regards the 1960 publications, Mr. Gregotti suggested that those mills which have technicians who know English should assist in translating the TAPPI monographs.

The specimen of the Italian translation of the monograph on "Paper Loading Materials" aroused a keen interest among technical people, so that similar efforts should prove very useful in forming a technical paper documentation in the Italian language.

On the ground of these considerations officers took upon themselves the following tasks, viz.:

Mr. Ridi: Monograph No. 18, "Water Technology in the Pulp and Paper Industry."
Mr. Gregotti: Monograph No. 2, "Saving Fourdrinier Wires."
Mr. Bersano and Mr. Restagno: Monograph in Print on "groundwood."
Mr. Cirla, Mr. Ghisoni, and Mr. Cartiere Burgo, Mantova: Monograph No. 10, "The Bleaching of Pulp."

Regarding then the translation of the Data Sheets, Mr. Cirla will examine the possibility of including such translation in the work program of the Testing Methods Committee. Should this not be possible, a group of technicians shall be appointed for this assignment.

The officers agreed on accepting the proposal sent to TAPPI by the management of the *Graphicus* magazine to have this magazine sent to all the Italian members of TAPPI.

This magazine will publish the reports of the Testing Methods Committee which also concern the graphic arts field, such as "Conditioning of Work Rooms," etc.

Mr. Bersano informed them of the tentative program of the Study Group of European TAPPI Members Conference to be held in Luzern on September 12–26 next.

MONDAY, SEPT. 12, 1960

10:00–12:30 & 2:30–5:30. Papermaking

1. The Problems of High-Speed Machines (Beloit).
2. Formation on the Wire (Film—Cartiere Burgo).
3. Adhesion to Couch and Presses (Mr. Hendry).
4. Drying (Mr. Nevrell).
5. Instrumentation.

TUESDAY, SEPT. 13, 1960

9:00–12:30. Education for Papermaking in Europe

1. A panel representing the educational institutes consisting of: Mr. Steenberg, Mr. Hudson, Mr. Brecht, Mr. Adamik, and a French representative. (The secretary will contact Mr. Centola in order to know his opinion as to the advisability of his attending this panel.)
2. A panel representing the paper industry: an Italian representative, a French representative, a Swedish representative, a British representative, a German representative, and an Austrian representative. (Officers invited Mr. Ghisoni to represent Italy at this panel and we are awaiting Mr. Ghisoni's answer to this respect.)

2:30–5:30. Two Discussion Sessions

1. How to Introduce the Educated Man into the Paper and Pulp Industry and Make the Best Uses of His Abilities (Mr. Rance and Mr. Steenberg).
2. The Efficient Utilization of Research Ideas in the Practical Field (Mr. Grünwald).

WEDNESDAY, SEPT. 14, 1960

9:00–12:30. The Sulfite Pulps

1. High Yield Sulfite Pulping (Mr. Borisek).
2. A General Discussion of Sulfite Pulping (under the supervision of Mr. Giertz).
3. The Present Situation in Bleaching (Mr. Giertz).

FRIDAY AND SATURDAY, SEPT. 16 AND 17, 1960

Visits to Attiesholz, Utsendorf, Deiswel, and Cham.

For the National meeting of "Poplar and Fast Growth Softwoods" to be held in Turin on April 24 and 25, 1960, organized by the Turin Chamber of Commerce, the "Instituto Nazionale per le Piante da Legno" and "E.N.C.C.," the cooperation of TAPPI has been requested for the development of the following program:

APRIL 23: Visits to the estates at Casale and Millerose.

APRIL 24: This day shall be devoted to the reports of agrarian technicians.

APRIL 25: This day shall be devoted to the industrial uses of national timber.

In the morning: The following papers will be delivered:

"Utilization of a Wide Variety of Fast Growth National Wood" (Mr. Bersano).
"National Wood Raw Materials and Their Use in the Paper Industry" (Mr. Bosso).

These papers will be followed in the same morning by papers delivered by other technicians on the utilization of national timber in industries not concerned with paper, such as furniture, plywood, etc.

In the afternoon there will be four panels on the following subjects:

1. Varietal Control (with the attendance of a TAPPI representative).
2. Mechanization of Plantations, Fellings, and Transports (with the attendance of two TAPPI representatives).
3. Piling up and Preservation of Timber in Stores (with the attendance of two TAPPI representatives).
4. The Italian Industries Using Poplar, and the European Common Market (with the attendance of Mr. Bersano, Mr. Bossi, and two other TAPPI representatives).

Therefore we should find seven TAPPI representatives.

1. "Varietal Control," with the attendance of Aron Levi of Cartiera Vita Mayer.

2. "Mechanization of Plantations, Fellings and Transports," with the attendance of Carlo Ruspa of Cartiere Burgo and perhaps of Domenico Galanzino, too, of Cartiera Italiana.
3. "Piling Up and Preservation of Timber in Stores," with the attendance of Giorgio Cerio of Cartiera Italiana and of Giuseppe Villa of Cartiera Villa.
4. "The Italian Industries Using Poplar, and the European Common Market," with the attendance of Mr. Bersano of Cartiere Burgo, Giacomo Bosso of Cartiere Bosso, Vittorio Gilberti of Cartiere Donzelli, and of Flavio Frabetti of UTILE Co.

FINANCIAL SITUATION

Mr. Bersano stated to officers that the accounting period for 1959 closed with limited assets.

After examination of the 1960 estimate balance sheet officers resolved:

1. To call for funds—as already done in the last few years—of the supporting mills, addressing a copy of the letter to the person who will be able to take care of this matter.
2. To ask the New York TAPPI Headquarters whether it would be possible to get a contribution for the Italian translation of the monographs and their printing costs.
3. To increase the annual dues of Associate Members for 1961. Such increase from Lit. 3000 up to Lit. 5000 will be communicated at the middle of 1960.
4. The translated monographs will be distributed free at a rate of one copy per each member and all the additional copies requested by TAPPI members or by other outside people will be sold at the price of Lit. 2500.

Information will be given in the Italian *TAPPI Bulletin.*

The British Technical Paper Association have sent the program of the meeting which will be organized in London on March 23 and 24, and have invited one or two representatives of the TAPPI Italian Section to attend such meeting as guests of the British association.

The meeting ended at 12:30.

Kalamazoo Valley

Chairman Otto W. Kroeschell welcomed the 150 guests in attendance at the third meeting of the year of the Kalamazoo Valley Section which was held in the afternoon and evening of Dec. 3, 1959, at Inman's Restaurant, Galesburg, Mich. The meeting was then turned over to James W. Winn, program chairman for the meeting, who introduced the speakers.

The first speaker was John Vanderhoff, associate scientist of Dow Chemical Co., Midland, Mich., who spoke about the "Mechanism of Latex Film Formation." Vanderhoff discussed the theoretical aspects of film formation and with the aid of slides and motion pictures of specially prepared latices of 1.5 to 2.0 μ diam. due to the limitations of the ordinary light microscope, showed the films being formed. These pictures enabled one to see the Brownian motion of the latex before drying, the convection currents in a drop of latex as it dries and the spontaneous crystallization which takes place at about 75% solids when motion stops and film formation starts. The use of a plasticizer does not alter the mechanism of latex film formation, it only lowers the viscosity of the latex particles or the forces which resist deformation of the particle.

Speaking on "Synthetic Polymer Emulsions in Pigmented Paper Coatings," Paul J. McLaughlin of Rohm and Haas Co., Philadelphia, Pa., pointed out the rapidly increasing demand for coated papers in packaging and other fields. He mentioned the small binder to pigment ratio in paper coating versus paints and how the binding in paper coating is in effect accomplished by "spot-welding" the pigment, as opposed to a nearly continuous film of binder in paints. After tracing the development of binders from the natural water soluble materials such as starch and casein to the synthetic polymer dispersions, McLaughlin discussed the variables affecting the performance of polymer dispersion binders. These variables were the polymer hardness, functional groups present in the polymer, and the molecular weight of the polymer.

Robert W. Hagemeyer of Wyandotte Chemicals Corp., Wyandotte, Mich., who summarized the findings of TAPPI Project No. 600—"The Effect of Pigment Combination and Coating Solids on Particle Packing and Sheet Characteristics," was the third afternoon speaker. This paper appeared in the March, 1960, issue of *Tappi.*

"The Past, Present, and Future of Coating" was the subject of the after-dinner speaker Harold Annis of Oxford Paper Co., Rumford, Me., and also vice-president of TAPPI. Starting in the mid-1930's with the development of on the machine coating, Annis presented some of the more significant developments which have brought the production of coated papers to its present high annual tonnage. Significant was the tremendous amount of research time and money spent by both suppliers and consumers (paper producers) on basic studies of the behavior of pigments and binders.

Meeting the challange of higher mailing costs by lowering the weight and caliper of coated paper without sacrificing quality is one example of the industry's ability to satisfy the purchaser. The lower weights brought up another problem which was solved by the development of pickup felts. Increased competition by lowering the price of paper has resulted in a demand for higher production rates and consequently new problems in control in order to maintain quality. He stressed that before any high-speed coating, on or off the machine, is started, the wet end of the paper machine must be under control. High velocity coating is a desirable development especially as to cost and space when modernizing existing coating equipment.

In regards to supercalendering, Annis thought that too much emphasis was put on high supering for maximum smoothness and gloss thereby lowering impression tolerance on printing presses. Instead of this, the stock should be supered to optimum printability. Formulations of coating colors which will eliminate the need of supercalendering will be a great stride forward.

January, 1960

The silver anniversary of the joint TAPPI-PIMA "Paper Makers Get-together" drew nearly 500 persons to the Hotel Harris in Kalamazoo on Jan. 21, 1960. Many of the papermakers attending the fourth annual Pulp and Paper Conference at Western Michigan University were in attendance as well as many former residents of the Kalamazoo area.

Edward McFaul, Chicago management consultant and university professor, in his talk on "How to Keep Your Foot Out of Your Mouth," warned the audience of the misunderstandings which arise through the careless use of words in communication. His talk illustrated the conversational pitfalls existing on the job and in the home by use of scores of anecdotes.

R. G. Macdonald, assistant to the president of national TAPPI, and Harry Weston, national PIMA secretary-treasurer, traced brief histories of the local chapters of the two organizations.

Toastmaster for the "Get-together" was L. D. Nicholson, vice-president of Hamilton Paper Co., Michigan Div. in Plainwell.

New England (Eastern District)

The Eastern District held a dinner meeting on March 7 at Armand's Beacon Terrace, Route 9, Framingham, Mass. Seventy members were present and enjoyed a delicious filet mignon dinner.

After the banquet John Wendell, chairman, welcomed those present, invited them to attend the annual meeting in June at the Chatham Bars Inn and then introduced Jim Field, local

section assistant of National TAPPI who spoke briefly on the efforts of National TAPPI to coordinate the activities of local sections.

John Lewis, chairman of the New England Section, was introduced who urged the members present to attend the next section meeting to be held at Storrowtown Tavern, at which time Dr. Nissen will speak on hydrogen bonding. The time for this meeting is 7:00 p.m. Mr. Lewis also mentioned that preparations are being made to form a new Western District of the New England Section.

Roger Wiewel, program chairman, introduced James S. Thornton, Frank W. Egan Co., who presented an illustrated talk on the equipment and equipment costs necessary for extrusion coating. Richard Loheed, Charles T. Main, Inc., discussed some of the operating variables associated with extrusion coating. A lively discussion period followed at which time both speakers attempted to answer each question.

D. W. Lovering, *Secretary*

Ohio

The February meeting of the Ohio Section of TAPPI was held at Swifton Center, Cincinnati, Ohio, and included a tour of the Evendale plant of Formica Corp. One-hundred and fifty people participated in the plant tour, while 254 were present for the dinner meeting.

A paper prepared by William F. Drees, vice-president Research and Planning for the Formica Corp., was presented at the dinner by Larry Isaacson. Mr. Drees's paper was entitled "Research and Development at Formica." Mr. Drees was unfortunately unable to be present because of illness.

George E. Martin, *Recording Secretary*

Southeastern

The southeastern Section of TAPPI held their annual Jacksonville meeting on January 22–23 at the Roosevelt Hotel. The group was welcomed by W. B. Jobbs, Jr., mill manager of the Owens-Illinois Glass Co., Mill Division, at Jacksonville.

The technical program included the following:

"Use of Titanium Equipment in Chlorine Bleaching, by Henry B. Meier, Riegel Paper Corp.
"Production Use of the Accuray and Hygrotester," by W. K. Burland, Container Corp. of America.
"Some Recent Researches on Paper Making," by Roy P. Whitney, Dean, The Institute of Paper Chemistry.

The first paper reviewed the application of titanium to chlorine dioxide bleaching equipment. Particular attention was called to a titanium lined chlorine dioxide mixer in service since December, 1955.

The application of the Accuray and Hygrotester to moisture and basis weight control was described. Variation has been reduced and quality improved through the use of the equipment.

Dr. Whitney was the feature speaker of the evening. He described recent research in the removal of water from dilute suspensions of fibers. This work has given a better understanding of filtration and drainage on the paper machine.

On Saturday morning, a visit to the Owens-Illinois mill was made by 55 members of the Section.

A point of interest at the meeting was the attendance of several high school and guidance counselors.

Production Use of the Accuray and Hygrotester

William K. Berglund

Most of you already know that the control of basis weight and moisture content of linerboard as it comes off a high-speed linerboard machine is of major concern to the paper maker. He wants a sheet of uniform formation which in turn gives a more uniform and more easily controlled moisture level. Paper quality is a function of the pulp mill that provides the machine with the raw material necessary to make a sheet with acceptable characteristics such as burst, tear, tensile strength, etc. The papermaker accepts this pulp stock and attempts to form a sheet with uniform caliper and weight that is free of wet streaks.

These two very important variables, weight and moisture, have been controlled as best we can with the use of laboratory basis weight scales and laboratory moisture meters. Both of which, we must realize, are inadequate for controlling today's high-speed machine and are inadequate for satisfying greater customer demands for a more uniform paper.

It was these facts which led us to consider and finally purchase instruments for continuously measuring basis weight and moisture. After careful consideration we purchased and had installed an Accuray, which is manufactured by Industrial Nucleonics, Inc., and a Hygrotester manufactured by the Paul Lippke Co. of Germany. These were installed on our no. 2 paper machine in July of 1957. The Accuray is for the measurement of basis weight and the Hygrotester for the measurement of moisture.

I am not going to present a technical evaluation of these two instruments nor a detailed explanation of their theory of operation. What I want to tell you about is a method that we have found satisfactory for using these process control instruments for controlling basis weight and moisture.

However, for the benefit of those who may not be at all familiar with the two instruments and how they perform, the following may be helpful:

The Accuray has a radioactive source in what is called a detector head that rides on a track mounted over a drier roll on the paper machine over which the paper is passing. This is the primary measuring element. Its output signal amplified and displayed as pounds per thousand square feet is recorded on a strip chart recorder at the dry end of the machine and on a repeater strip chart recorder at the wet end of the machine. The dry end recorder has two chart speeds, one gives $^1/_2$ in. of chart travel per sheet scan and the other speed gives 5 in. of chart travel per scan. This is selected at the recorder. At the wet end of the machine there is also a detector head position indicator that tells the machine tender at just what position the detector head is in. This indicator is graduated according to the headbox slice positions. These two together tell the machine tender: (1) how much the sheet may be light or heavy and (2) at what position on the machine headbox to make corrective adjustment. On our machine the detector head scans the sheet as it passes over the top intermediate drier located between the calender stacks.

The detector head scans the sheet from back to front every 3 min. and automatically standardizes itself every 30 min. It also automatically moves off of the machine when the sheet breaks.

The scanning detector or shoe of the Hygrotester scans the sheet as it passes between the 2nd calender and the reel drum. The signal from the shoe is recorded on a profile strip chart recorder as per cent moisture at the dry end of the machine. It is also recorded on a dot strip chart recorder as average moisture. This average is recorded every 20 sec. and records while the shoe is moving in either direction—front to back or back to front of the machine. The machine tender has a per cent moisture indicator and shoe position indicator also. This position indicator is also graduated in machine headbox slice positions.

We have now taken these two instruments and established a procedure for using them that makes everyone well aware of their presence and causes complete dependence on them for weight and moisture control. Their reliability has been proved to the machine crews. Instead of the paper tester

William K. Berglund, Staff Technician, Container Corp. of America Fernandina Beach, Fla.

weighing a few (in our case 8-sq. ft. samples) square foot samples from each reel of paper on a laboratory basis weight scale, he goes over to the strip chart recorder in the middle of a reel and just before the reel is turned up and turns the chart speed to the faster position. At the completion of the scan he turns the recorder off and uses the center line of the adjustable scale to locate the average weight of the scan. He records this on the laboratory report as average reel weight. This scale is also divided into machine headbox slice positions and he can quickly determine at what position on the machine that basis weight is out of weight limits. These "out of limit" weights are also recorded on the laboratory report. At the completion of this weight check the paper tester returns the chart drive to the slower speed. The back tender can then watch the chart for machine direction variations in weight. The chart speed selected at the dry end recorder does not affect the chart speed at the wet end, so that the machine tender has an unbroken record of MD variations.

The moisture check for each reel is made in much the same way. The paper tester turns the profile recorder on and as the shoe starts to make a scan from the back to the front of the sheet, the signal is received by the profile recorder. After the scan record is made the tester positions a movable hair line to the average of the scan and records this value on the report.

The door glass on the front of the profile recorder is marked off in slice position divisions, and any "out of limits" points are noted. Current limits are 5 to 8%.

An additional duty of the paper tester is to stand by the Accuray control panel during an extended paper break or weight change and remotely position the detector head over the tail as it comes over the drier, thus giving the machine tender an immediate check on weight. He also changes the range selector switches on the control panel to select the appropriate instrument ranges for the different grades. This gives a center scale reading for each grade that we run.

Thus, by this method of weight and moisture determination we are accepting or rejecting our entire machine production. The operating crews have a continuous check on the production; we have a continuous, complete record of it. Immediate plans for the future are to have a slot made in the bottom of each recorder so that the chart feeds out the bottom of the case and can be torn off at the end of each reel turn up. This chart will then be stamped with the time, reel number, burst data, and other test results and filed with the daily production records for as long as we feel is necessary. We are also investigating a digital readout system for averaging the scans.

I believe that this continuous testing and hence controlling of weight and moisture may be a first in the paper industry.

An Accuray is checked once each 8-hr. shift in a way we have found to be very reliable and perhaps unique. We have a linear footage counter at the rewinder that is turned on at the start of the rewind of the reel. We use this total figure along with the entire trim width and total scale weight and calculate the average weight per thousand square feet. This is compared with the average estimated weight of all of the scans made by the instrument during the reel turn up. The results usually agree within a few tenths of a pound basis weight. The Accuray is also checked weekly by the Instrument Department with standard calibrating plates.

The Hygrotester is checked weekly by the Instrument Department with a standard calibrating plate and weekly by the Technical Department with oven dried samples.

I have attempted to outline our product control procedure. We believe the instruments along with an exact procedure for the operating crews to follow in using them has greatly improved the uniformity of our linerboard. It has resulted in less rejected board on grade changes and machine startups.

I should mention in closing that the use of these two instruments in experimental work that has been started in investigating the machine steam system, condensate removal system and the secondary process systems on the machine is of equal if not greater importance than their use as a product quality control tool.

Presented at the Southeastern Section of TAPPI, held in Jacksonville, Fla., Jan. 22–23, 1960.

Some Recent Researches on Papermaking

Roy P. Whitney

In terms of the age of the paper industry, the continuous paper machine is a relatively recent development. It was the invention of Nicolas-Louis Robert in France in 1798, but it fell to the Fourdrinier brothers in England in the early 18 hundreds to develop the machine, make it practical, and give it a name. There have been many improvements since, of course, and today's giant machines here in the south would seem to bear little relation to the original fourdrinier. Actually, the fourdrinier is still almost completely unchanged in principle from the earliest models. Its evolution, particularly toward increased widths and speeds, has aggravated inherent problems which probably were not known to exist in the early years of the machine, and today it is more than ever essential that we gain an increased understanding and control of its operation. It is my personal belief that more progress has been made toward this understanding in the past 10 to 12 years than was achieved in the hundred years preceding this period, and I want to discuss some of this relatively recent research. Perhaps we should also ask ourselves whether or not the experience of the past 160 years has suggested any inherently better techniques for making paper.

The manipulations essential to the preparation of a sheet of paper from a water suspension would seem to the uninitiated to be relatively simple. While there may be several possible approaches, we might set up the requirements this way: First, we need a uniform, completely dispersed, dilute suspension of cellulose fibers. We know, of course, that these fibers must have been refined in order to give us the characteristics we desire in the finished sheet, and that for a variety of reasons we need several other ingredients beside fibers in our furnish. However, let's keep our model system as simple as possible. Next, we need some sort of "forming" device to spread the fibers out into sheet form and get rid of most of the water. In its simplest manifestation, this still seems to require a screen fine enough to catch the fibers as the water flows through. So we just introduce our ideal suspension to the forming device, without causing or permitting any disturbances or changes which would interfere with uniformity, drain the water away, remove the mat and dry it, and we have a well-formed sheet of paper.

Unfortunately, numerous complications arise in actual practices, as you well know. The first one is that we usually compromise with ideal conditions for the sake of the economy and the practical limitations of commercial production.

In our present-day, continuous sheet-forming systems, whether fourdrinier or cylinder machine, we have so far found it impossible to meet even the first requirement—that of starting with a uniform, completely dispersed fibrous suspension. The fibers have remarkable desires to flocculate into clumps and agglomerates. While this agglomerating tendency can be discouraged by certain chemical additives, complete dispersion requires that we go down to furnish consistencies in the range of 0.01 to 0.001 of 1%—a level much too low to be feasible commercially.

Since we can't prepare and maintain a dispersed slurry, we try to break up the flocs just before the furnish flows into the forming device. I would venture to observe that we still have some things to learn about how best to accomplish this.

By a variety of means, we cause to flow into the former a

Roy P. Whitney, Vice-President, The Institute of Paper Chemistry, Appleton, Wis.

$$\frac{dV}{d\theta} = \frac{A\Delta P_f}{\mu(W/A)R}$$

Constant Rate

$$R = \frac{A^2}{\mu C(dV/d\theta)^2} \frac{\Delta P_f}{\theta} = B \frac{\Delta P_f}{\theta}$$

Constant Pressure

$$\frac{\Delta\theta}{V\Delta} = \frac{\mu CR}{A^2\Delta P_f} \quad V = B'RV$$

Fig. 1

slurry of *quite* uniform consistency, *more or less* evenly distributed, and *not badly* flocculated. Our problem now is to remove the water and form the sheet without permitting disturbing influences to upset the system and to impair sheet formation. By-passing for the moment such extraneous disturbances as vibration, inertial and direction effects and the like, it is probable that the tendency of the fibers to flocculate again during drainage is the most serious deterrent to good formation. Thus, we are led to the conclusion that *papermaking in its simplest and most basic sense is essentially a competition between two rates—the rate of drainage on the one hand, and the rate of fiber flocculation on the other.* We need to get the water out of the slurry before fiber flocculation has had time to take place to a detrimental extent. The problem is further complicated by the fact that neither rate is independent of the other.

I'm sure you realize that I am presenting an oversimplified picture, particularly to focus attention on the essentials. Among the other factors which affect the papermaking operation, two stand out as being of great importance. These are the instability of the wet mat during formation, and the profound effect of the fines on both drainage and sheet properties. I shall have more to say of these as we go along.

For reasons which I have tried to outline, much of the basic research on papermaking during the past few years has been concentrated in two areas—studies of the drainage of water from fibrous suspensions, and studies of fiber flocculation. Of the two, by far the more effort has gone into the drainage study, and the more progress has been made. Although the flocculation of fibers has been studied sporadically for many years, and is now being attacked more systematically in several laboratories, our understanding of this phenomenon is still nebulous. Any adequate insight as to the interaction of the two processes of drainage and flocculation is still in the future, and this of course is of greatest interest from the practical papermaking standpoint. The recent work on drainage is highly significant, in my judgment, and it is this which I want particularly to discuss.

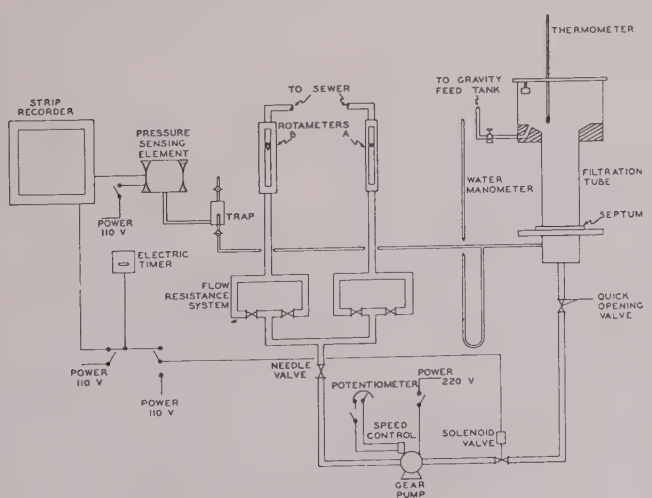


Fig. 2. Constant-rate filtration apparatus

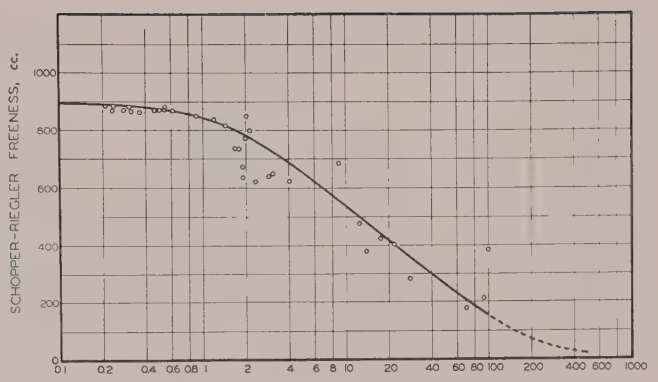


Fig. 3. Filtration resistance, $R \times 10^{-8}$, cm. per gram

Now, if we are going to try to understand quantitatively the drainage of water on a paper machine—any kind of a paper machine—we must have a physical picture with which to work. The simplest one is the engineer's old standby—the concept that the rate at which an operation proceeds is directly proportional to a driving force and inversely proportional to an opposing resistance. Such a relationship is expressed by the first equation on Fig. 1. The same relation, with different symbols, is used to express the rate of heat transfer, or mass transfer. When applied to the flow of electric current, it is called Ohm's Law. When applied to filtration, as in this instance, it is d'Arcy's Law.

Filtration can of course be conducted according to any desired schedule of externally imposed conditions. A constant-rate schedule turns out to be very useful in experimental studies. A constant-pressure-drop schedule is of great commercial interest in the paper industry, since washers, cylinder machines, suction boxes, suction couches, even table rolls, approximate this schedule of operation. You see d'Arcy's equation rearranged for these two cases in Fig. 1.

Our approach to a quantitative understanding of drainage, on any kind of equipment, must be through an understanding and an elucidation of the various terms in this equation. Of these, two—the pressure drop and the resistance—are the vital ones. Let's take a look at them generally, and then try to apply what we learn to a few specific cases.

The pressure drop, which is the driving force causing filtration, is usually well-defined and easily measured. On an open cylinder, it is the head difference from outside to inside. On a suction box or suction couch, it is the vacuum maintained on the inside. On a table roll, the situation is not at all simple, however, and we shall have to consider this later.

Turning to the resistance term, the concept of an "average specific filtration resistance" can easily be demonstrated to have validity for a filter bed comprised of noncompressible

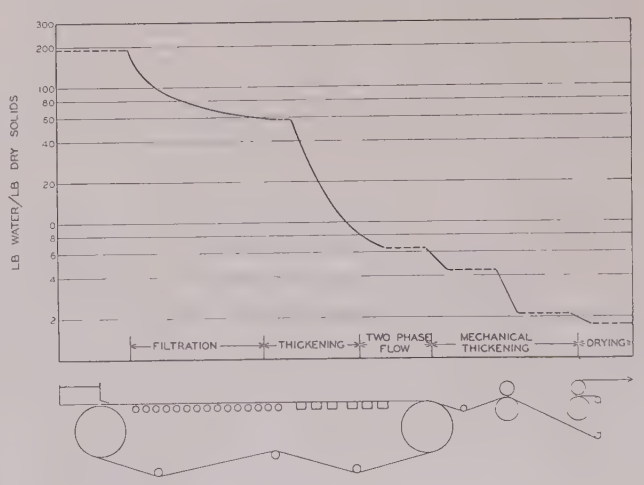


Fig. 4. Water removal on wet end of fourdrinier

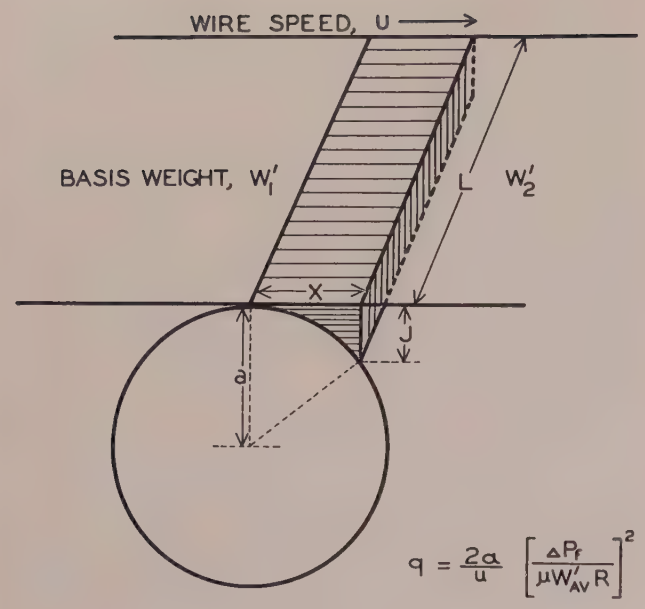


Fig. 5

particles like glass beads or sand. In such cases, the specific resistance is essentially independent of the externally imposed conditions like the pressure drop. There has been a great deal of research at the Institute during the past ten or so years to prove that the specific resistance concept is also valid for a bed made up of a compressible material like cellulose fibers. I don't want to dwell on the background work this evening, because I expect many of you are familiar with it. Filtration resistance is coming to be recognized as an important property of a pulp slurry. It has a much wider utility than in drainage studies, but we won't have time to get into that this evening.

Filtration resistance can easily be measured in the laboratory, in an apparatus such as shown in Fig. 2. Either a constant pressure or contant rate schedule can be used, although the latter is much more convenient and yields a result more nearly free from the effect of creep. The resistance depends greatly on the nature of the furnish—the kinds of fiber, how they have been refined, and particularly the amount of fines and debris present. It also depends greatly on the pressure drop across the mat; since the fibers are compressible, the greater the pressure the greater the degree of compaction of the mat, and therefore the greater is its resistance to fluid flow. Measurements on various pulps and furnishes have yielded specific resistance values covering more than a thousandfold range.

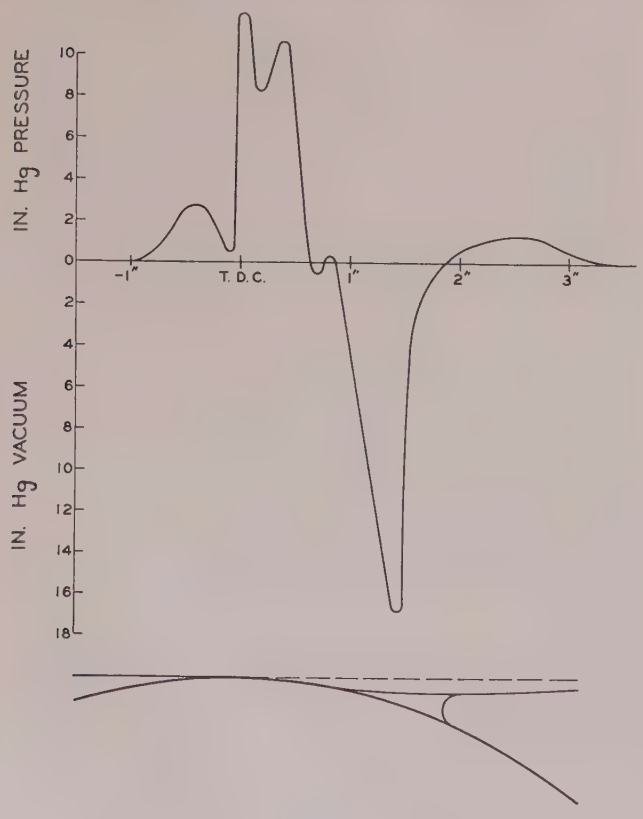


Fig. 6

Freeness is an inverse qualitative measure of drainage resistance, but the freeness test is empirical and uncontrolled, and it cannot be interpreted quantitatively and applied to the operation of commercial equipment. Figure 3 shows some data comparing freeness and filtration resistance. You can see the insensitivity of freeness, particularly in the high and low range.

Now, with this much background, our object is to try to apply these concepts of driving force and resistance to various commercial equipment to see what we can learn. Probably the most complicated and difficult example is the fourdrinier, but it is also the most important, so we may as well start there.

Let's consider for a moment a typical fourdrinier, operating on any common grade of paper. The one shown in Fig. 4 happened to be operating at quite a low speed, but the picture is the same at higher speeds. As you can see, the headbox consistency was about 0.5%, which gives rise to the figure of about 200 lb. of water flowing onto the wire for every pound of paper. The table rolls removed about 140 lb. of water, or 70% of that entering. About another 56 lb., or 28%, came out on the suction boxes and the suction couch. Removal of the remaining 4 lb., or 2%, was about evenly divided between the presses and the driers.

The importance of the table rolls as water-removing devices is apparent from these figures. But this was not always recognized; table rolls were in fact originally conceived and employed soley to support the wire while the sheet was being "formed." But as machine speeds increased, it became apparent that they were moving a great deal of water, and that they must, by some means not understood, be acting as suction pumps. Although the nature of this pumping action was speculated upon as many as 30 years ago, it has only been within the past decade that a logical interpretation of the phenomenon has been developed.

You are well aware that drainage at a table roll takes place in the "nip" downstream from the point of contact between wire and roll, as indicated in Fig. 5. This is a very small distance compared with the roll diameter, and is of course not nearly so large nor so well defined as this diagram would suggest. Nevertheless, this is the critical area, and we must try to understand what goes on here. To do so, we must consider the driving force and the resistance separately.

Until 1950, the only driving forces recognized at the nip were the small hydrostatic head of slurry on the wire, and the slight suction leg represented by the "nip." These were at most an inch or so of water, and could not begin to explain the high drainage rates or the fact that the rate increases so greatly with speed increases. Through a remarkable theoretical analysis by Sir Geoffrey Taylor at Cambridge University and some ingenious experimental work by Peter Wrist who was then at the British Paper and Board Industry Research Association, we now know that the major driving force is a suction developed in the downstream nip between wire and table roll. This suction is related to the kinetic energy of the flowing stock and consequently increases with the square of the machine speed. In fact, Taylor's equations indicate that the suction reaches a maximum value of 34 ft. of water—that is, a perfect vacuum—at a machine speed of 2800 f.p.m. Actually, because of the evolution of air and boiling of the water

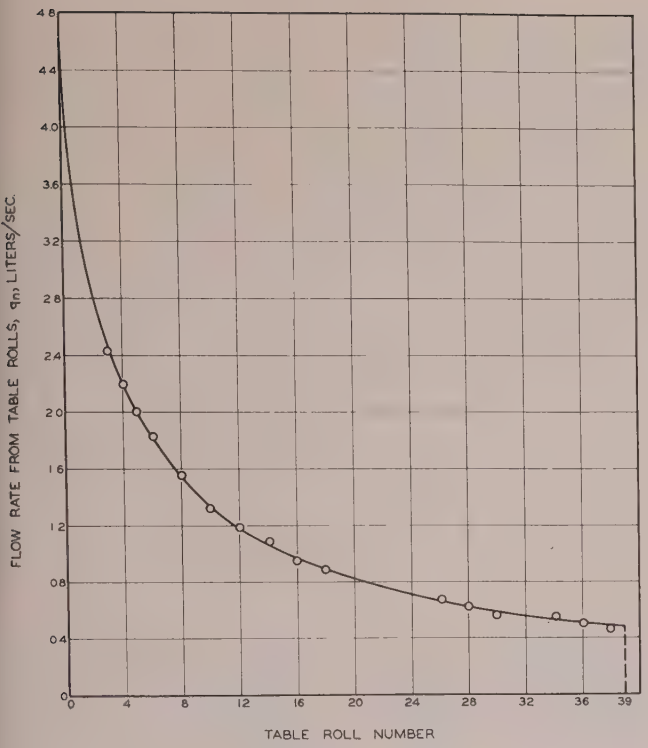


Fig. 7

at the very low pressure, the maximum suction effect of the table roll is reached at about 2500 to 2600 f.p.m. Boiling in the nip at these speeds has been observed in high-speed movies. For the first time, therefore, we have a concrete physical picture of table roll action, and also a concrete limitation on machine speed, for the conventional fourdrinier. Above about 2600 f.p.m. the suction stays constant, and we must increase the number of table rolls in direct proportion to speed increases in order to maintain equivalent drainage.

Figure 6 shows a pressure profile at a table roll, and is taken from Wrist's work. You can see that the picture is complicated, and also the small area over which there is a driving force to cause drainage.

Now we have to see if we can apply the resistance concept at a table roll, and this also turns out to be complicated and difficult. We know now how to measure resistance in the laboratory, but we don't known whether this value can be used to calculate drainage at a table roll. In order to find out, we need drainage measurements at individual table rolls, and this is not easily done, particularly at high speeds. There have been a few such measurements, and I shall refer to some taken on the same fourdrinier referred to earlier. It was running on bond paper, at about 350 f.p.m.

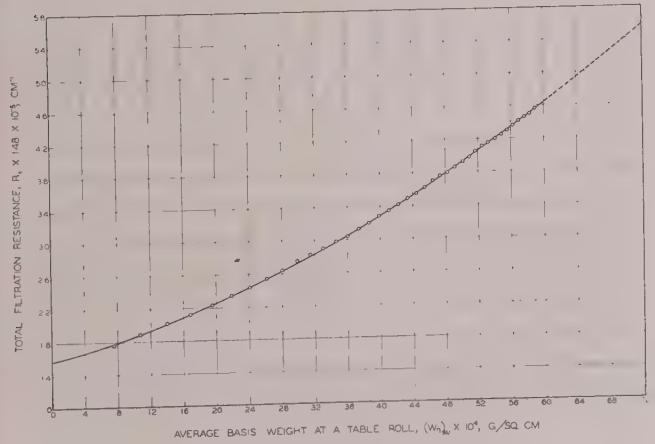


Fig. 8

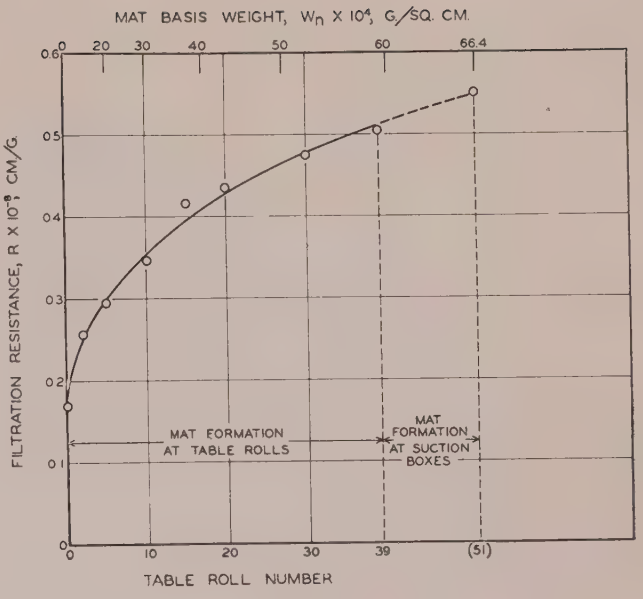

MAT BASIS WEIGHT, $W_n \times 10^4$, G/SQ. CM.
FILTRATION RESISTANCE, R X 10^{-8}, CM/G.
MAT FORMATION AT TABLE ROLLS
MAT FORMATION AT SUCTION BOXES
TABLE ROLL NUMBER

Fig. 9

Figure 7 shows the flow rate from individual table rolls. As you well know, the flow rate drops off very rapidly as the basis weight of the sheet builds up.

Now, if we determine the pressure driving force from Taylor's equation, we can calculate the total resistance at each table roll by a process of graphical integration. As you see in Fig. 8, the total resistance goes up as the basis weight increases, but if this were the only effect, the line would be straight. Since it curves upward, the specific resistance is increasing also—that is, more than the basis weight is influencing the resistance. The basis weight can be calculated from drainage rate and consistency, and also checked by taking scoop samples on the wire. Introducing this quantity permits us to calculate the specific resistance, shown in the next slide.

You see in Fig. 9 that the specific resistance, which is independent of basis weight, does indeed increase as we go down the wire. Without making a long story of it, the reason is known to be the greater retention of fines as the sheet gets thicker. Fines have a tremendous effect on filtration resistance, and this must always be reckoned with. You might make a mental note of the approximate value of the resistance—from about 0.2 to 0.5 in these units—so we can compare it with laboratory values.

In Fig. 10 we have the laboratory measurements of filtration resistance of the stock taken from the end of the table roll section. To make our comparison, we must know the effective pressure drop developed by the table rolls, and this can now be calculated from the machine speed. The maximum suction turns out to be 10 cm. of water, and the average about 5 cm. of water. Taking 5 as representative, you see that the laboratory resistance is about 3.5, compared with about 0.5 on the machine. This is a considerable discrepancy.

Now, there are a number of reasons for this difference—flocculation on the machine and not in the laboratory, for instance—but the overwhelming reason has to do with the way the pressure is applied on the machine. The nip length is short compared with the wire length between nips, and the pressure is applied only in short impulses, which on this machine were of about 0.01 sec. duration. Under these conditions, the mat just never reached an equilibrium degree of compaction. Furthermore, the mat tends to be expanded as it comes into a table roll because water may be thrown up through it from the run-around on the roll. You may remember Wrist's data which showed a positive pressure upstream from the nip.

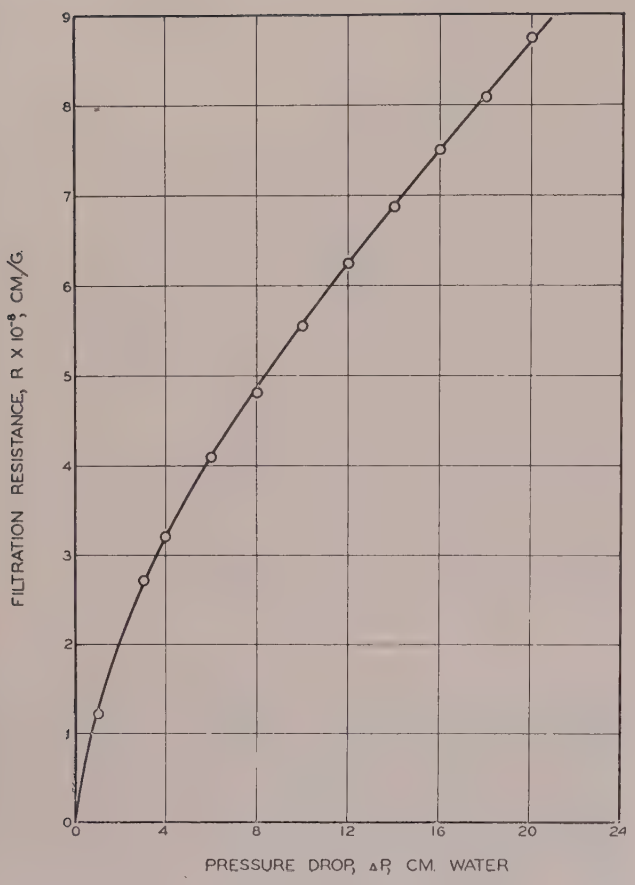


Fig. 10

There has been a lot of work, which is still in progress, on the behavior of wet mats under pressure impulses of very short duration, and we think we are making progress. In the meantime, it has turned out that it is quite possible to apply empirical correction factors which permit laboratory resistance values to be used in machine design, and we have been able to predict the behavior of table roll sections with considerable accuracy.

We could go on and on, and discuss the application of these concepts to many different cases. However, it is getting late, and you would soon be bored if you aren't already. I picked table rolls for particular discussion because they are the most difficult, the analysis is most unsatisfactory, and they are the most important water removers in present-day machines. In the case of suction boxes, couch rolls, etc., the pressure drop is easily determined, the laboratory resistance values can be applied directly, and we can do a good job of analyzing and predicting performance.

To us, the most exciting utility of these new concepts is in paper machine design. We look forward to the day when laboratory measurements on a desired furnish can be used, in conjunction with an adequate understanding of the principles and the phenomena involved, to design on a quantitative basis the ideal paper machine for handling this furnish. That day is not yet here, and there are many complex problems yet to be resolved which I have ignored completely, but we feel that the goal is attainable. In one or two cases, we have studied a certain furnish, predicted its behavior at a given speed, and then made extensive measurements on an operation to check up on our predictions. While there have been discrepancies, the attempts have been most encouraging.

It would be premature to suggest that the fourdrinier is becoming obsolete, yet, as you well know, there is much interest in other means of wet forming. This interest has undoubtedly been encouraged, in part at least, by the strong trend toward increased machine speeds and the inherent difficulties which the higher speeds exaggerate. It is almost axiomatic that sheet formation and uniformity deteriorate rapidly as speed is increased. From only the standpoint of fiber flocculation, one would predict that sheer formation should be improved at higher speeds, since the time available for flocculation decreases. The difficulty is not fiber flocculation, but undoubtedly is due largely to greatly exaggerated mechanical disturbances, particularly in the table roll section. When one observes the vibrations, the waves, the water sprouts, and all of the other effects, particularly violent at the very low consistencies near the slice, he wonders not only how a mathematical analysis could possibly be applied to such a system, but how paper can be made at all. In spite of the complexities involved, recent research at the University of Michigan—research sponsored by TAPPI—suggests strongly that some of these difficulties are inherent in the table roll action. While the table rolls may be very effective as water removers, they would seem to have serious deleterious influences on sheet properties at high speeds.

The research which I have discussed has led to significant new understanding, not only of the existing papermaking techniques but also of the requirements for improved forming methods. It is essential that it be continued, for like most research it has raised as many questions as it has answered. It is not necessary, however, that new developments await a complete understanding of the field, and this of course is never the case. In the last decade, we have witnessed notable contributions toward improved forming devices. The most promising of these seem to embody some sort of hybrid or combination of the fourdrinier and the cylinder machine. The suction breast roll, for example, now used commonly for high-speed tissue machines, is essentially a cylinder with a headbox mounted over it. It would seem to suffer from one of the major faults of the conventional cylinder, in that an essentially stagnant body of dilute slurry is being "scrubbed" by the moving wire and wet mat which it is accumulating, and the resultant shear forces give rise to a variety of sheet formation difficulties.

The vacuum formers, of which several types have been proposed, would appear to offer a more promising approach. All employ some means for attempting to reduce the excessive disturbances caused by free-surface flow on the fourdrinier or by the scrubbing action in the stagnent cylinder vat. In the Stevens former, for example, the dilute incoming furnish flows around the cylinder, through a channel of decreasing cross section, so that as drainage takes place it should be possible to maintain the relative speeds of the cylinder wire and the furnish nearly constant. Incidentally, the vacuum formers offer a case where the concepts of driving force and resistance which I have discussed can be applied in design more rigorously than with the fourdrinier, and this is being done.

Other relatively new developments in paper machine wet ends are interesting. The replacement of all of the table rolls by suction boxes has been tried on commercial high-speed machines. The Inverform process in England employs both a bottom and a top wire, with the stock fed into the wedge between the two, and drainage both up and down. Multi-ply sheets can be formed through the use of several top wires, and speeds in excess of 3000 f.p.m. have been reported.

While none of us here will see the complete obsolescence of fourdrinier, I think that we shall see other types of wet formers in widespread and successful operation on many grades of paper. At the same time, it should be noted that none of the new forming devices so far proposed seems to approach the fourdrinier in versatility and in the wide range of conditions over which it will operate successfully. The next few decades will be interesting ones in the papermaking field.

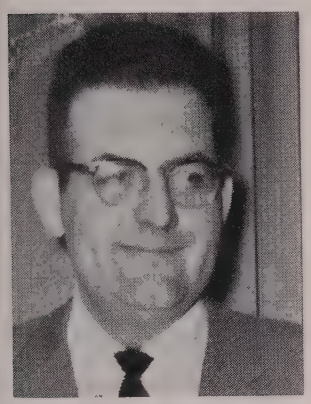
Presented at the meeting of the Southeastern Section of TAPPI, held in Jacksonville, Fla., Jan. 22–23, 1960.

Pacific

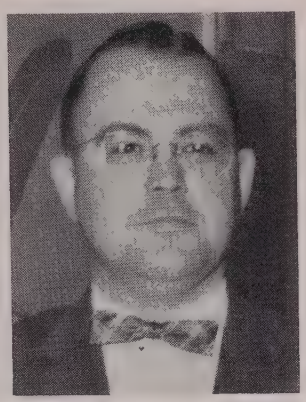
Pacific Section of TAPPI held its third meeting of the year in Longview, Wash., Jan. 19, 1960, at the Monticello Hotel. This was an engineering meeting and was moderated by B. W. Gibson, Chief Design Engineer of the Longview Fibre Co.

The program starting at 2:00 p.m. saw four papers given and with extensive discussion periods after each paper. The meeting lasted till after 5:00 p.m. The following papers were presented:

1. "Engineering Evaluation No. 3 Paper Machine Rebuild," by George Robertson, Simpson Paper Co., Everett, Wash. [*Tappi* 43, No. 3: 189A (March, 1960).]
2. "Size Press Starch Control," by Jack Decker, Columbia River Paper Mills, Vancouver, Wash.
3. "Temperature Controlled Spent Sulfite Liquor Diversion System," by E. A. Woodworth, Crown Zellerbach Corp., West Linn, Ore.
4. "Black-Clawson (Pandia) Continuous Digester Operation at Potlatch Forests, Inc., Lewiston, Idaho, Mill," by Robert Linkhart and Tom Tudder, Potlatch Forests, Inc., Lewiston, Idaho.



Tom Tudder



E. A. Woodworth

Black-Clawson (Pandia) Continuous Digester Operation at Potlatch Forests, Inc., Lewiston, Idaho, Mill

Robert Linkhart and Tom Tudder

Potlatch Forests, Inc., entered the pulp and paper industry in 1951 at its Lewiston, Idaho, mill to make a quality product using wood not being utilized in its sawmills. The slabs resulting from the production of lumber made unusually good pulp chips containing a high sapwood content with long fiber and good strength characteristics. However, as the mill developed business in food board requiring quality printing, it was found that filler stock was needed to improve the sheet. This filler stock is supplied in other areas by hardwood pulp. An extensive research project was set up to see how this could be accomplished at our Lewiston mill. Included was a study of sawdust. It was found that sawdust from the large saws with wide kerf, normal to sawmill operation, had good fiber. Though many of these fibers were cut, this short fiber stock made good filler to blend with the pulp from regular chips. When discovered that sawdust tends to pack in a stationary digester, another method of cooking was sought. An experimental Pandia continuous digester was located in the eastern United States, and a shipment of mill sawdust was sent to this pilot plant operation where trial runs were made. A study of these runs showed that sawdust provided a satisfactory filler stock when cooked in the Pandia.

In October, 1953, a Pandia continuous digester was installed at Lewiston. This was a small four chamber unit with a single 15-in. Pandia screw feeder with a maximum production rate of 25 tons of pulp per day.

Robert Linkhart and Tom Tudder, Potlatch Forests, Inc., Lewiston, Idaho.

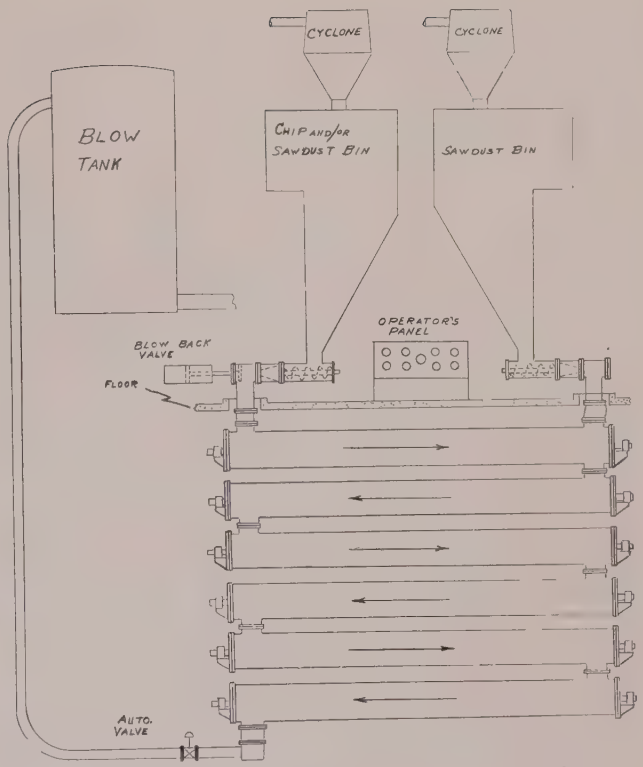


Fig. 1. Diagram of Potlatch Forests, Inc., continuous digester

Because of success of this unit and of plans for a large cylinder-type paperboard machine, a Pandia unit was designed and installed in 1955 for semikraft, high yield cook. The production from this unit was to be refined and used for filler stock in the inner plys of cylinder board.

In February, 1957, when the paper machine was changed to a fourdrinier, it became necessary to change to a full kraft cook producing bleachable grade filler stock to be blended before bleaching with regular pulp made from chips.

DESCRIPTION OF MECHANICAL UNIT

The Pandia unit consists of two 15-in. pandia screw feeders driven by individual 200-hp. a.c. motors through an adjustable speed dynamatic clutch and gear reduction unit, with a chain drive to the screws. Two feeders are used, because originally this pandia unit was fed with both chips and sawdust. Chips were fed in the no. 1 feeder which goes through all six chambers. Sawdust was added in the no. 2 feeder, which goes through only five chambers. Presently sawdust is used in both screw feeders. Speed of the screw feeders ranged between 20 and 60 r.p.m., depending upon the amount of filler pulp needed for the grades of paperboard being run on the machines.

Hot black liquor is introduced into the bottom of the hoppers above the screw feeders where it is used as a lubricating medium. These screws are manufactured of 316 stainless steel for maximum service life. When worn beyond tolerance, the screws are removed, overlaid, and reground in our machine shop. Special shop equipment has been developed by the company maintenance department for rebuilding and machining the feeder screws to very close tolerances.

The sawdust passes from the screw feeders through a restricted section where a plug is formed to keep the steam pressure of the unit from blowing back through the screw feeder. Beyond the plug section is the chemical inlet chamber, which is a large T where steam and liquors are induced into the sawdust, and these drop to the first digester screw. The blow

back valve, a large air operated piston with a plate to fit the plug section opening, is also located in the chemical inlet chamber. This valve is used on startup to build a plug in the chamber and in case of trouble on the screw feeders, to keep the steam from blowing back.

In the original installation the blow back valve was activated by a pressure drop in the chambers. This would close the valve when the pressure dropped, but the pressure would not drop until a blow back had already started. The electrical and instrument departments of the mill devised the present system which uses the amperage of the screw feeder drive motor to activate the blow valve. When the amperage on the motor drops below a preset point, the blow back valve will automatically close.

There are six 42-in. diam. by 40 ft. long screw conveyor digester tubes located directly below the screw feeders. These are driven by individual 7.5-hp. a.c. motors through an adjustable speed dynamatic clutch and gear reduction unit with a chain drive to the screw. The chamber screws are run at decreasing speeds from top to bottom to give maximum cooking time. We have found it very important to run the two top screws fast enough so that there is no buildup of sawdust in the chemical inlet chamber to cause a plugging of the screw feeder. Cooking time is determined by the speed of the screws, and can be calculated in minutes by dividing 180 by the average screw speed. For example, if the average screw speed is 5.0 r.p.m. then 180/5 = 36 min. The speed varies from 4.8 r.p.m. to more than 6 r.p.m. Average time from introduction into the feeder through cooking process and ejection into the blow tank is 42 min.

The impeller discharger is not run when the Pandia is using only sawdust since it has been found the sawdust pulp will pass through with the impeller down, thereby saving some power and eliminating another moving shaft under steam and liquor pressure—which is always a packing problem.

The standard orifice valve on the impeller discharge has been removed and a 6-in. air-operated Fabri-V-port metering valve has been installed. This valve is controlled from the operator's panel board and permits the operator to open the valve and allow any tramp metal or other foreign objects to be blown through. Prior to installation of this valve, we experienced considerable plugging of the discharger.

ACTUAL OPERATION OF THE DIGESTER

Sawdust from the sawmill is conveyed to two large steel storage silos by belts. Sawdust from two of our other sawmills is transported by truck and rail car and also stored in the silos. Fines from the chip screens and shavings from the sawmill planer are added to the sawdust to make maximum use of all the available wood fiber in producing high quality, easy bleaching pulp.

From the silos, the sawdust is blown about 400 ft. to steel hoppers over the screw feeders. Bin level indicators are interlocked with the blowers and turntable at the silo to automatically stop the supply of sawdust when the hoppers are full and to start again when the sawdust level goes down. By controlling the feed at the silos, the blowers seldom stop when the Pandia is operating.

We are presently using sawdust in both screw feeders, but satisfactory results have been obtained by using sawdust in one feeder and chips in the other.

MAINTENANCE AND DOWNTIME EXPERIENCE

One of the major maintenance problems we have overcome is that on the screw feeder. We use 316 stainless steel screws which when worn are overlaid on a welding positioner and reground to original dimensions. At one time the screws had to be changed every 2 to 3 months, but the present two screws have been in service for more than a year and are still in good condition. We attribute this extended life to the 316 overlay method of building up the screws, which gives a harder outer surface than the parent metal.

Packing the chambers and blow back valves has been a problem because of the steam pressure and liquor. We have had successful usage alternating rings of Johns-Manville C 2009, a teflon base packing, and 457-1513, a black liquor packing.

Our sawmill does not run on Sunday, and thus by Monday morning our sawdust storage silos are usually low, therefore the Pandia is shut down for scheduled maintenance work. At this time all chambers are inspected and repacked or packing is added as needed. The operator does his own packing adjustments and is required to make a complete inspection at least twice a shift. At the same time, the blow line is inspected, sections replaced as necessary, and all electrical equipment and instruments are checked out and adjusted. We have found that this 3- to 4-hr. shutdown once a week saves us from a forced shutdown due to packing blowing out, or other mechanical problems.

RESULTS OBTAINED

In an effort to improve the operation of this unit, an extensive study has been made of the pulp quality obtained. Precision instruments installed show that pressure is uniform throughout the unit, and temperatures are not as high as would be expected at the pressure at which the unit is normally operated. This was believed to be due to the false pressure developed by not relieving the noncondensable gases. An effort was made to bleed off these gases, but this was found impractical. Gases do not separate in this type unit as in a stationary digester where steam is fed from the bottom instead of from the top.

In the Pandia noncondensable gases appear to be consistently mixed with steam and are relieved through the discharger. Since steam is added at the feed inlets and at the second chamber, the temperature of the stock seems to decrease after leaving the second chamber. This is believed to be because of the heat loss of the chambers, even though insulated, and probably more so to an increase in the noncondensable gas concentration as the stock moves through the unit to the discharger. Typical temperatures obtained with 130 p.s.i.g. pressure are 345°F. in the second chamber, decreasing to 330°F. in the bottom (sixth) chamber. The temperature average is close to the 340°F. obtained in stationary digesters.

In other types of continuous cooking units, the temperature of the stock is reduced by the addition of black liquor or by dropping the pressure in stages. Both processes were tried, but no benefit was detected. A back pressure was found in the 6-in. blow line which is nearly 100 ft. long. Temperatures taken beyond the V-port discharge valve in the blow line range from 275° to 295°F. depending on rate of operation and discharge. As noted above, the temperature ahead of the valve in the sixth chamber is 10°F. lower than in a stationary digester.

It was found that desuperheating the steam just prior to entry in the digester gave a slight improvement to quality and prevented charring of the wood as it entered the digester.

Experience has shown that sawdust can be cooked to a permanganate number two to three points higher than chips, and still bleach properly after blending. This permits a higher strength and uses less white liquor. The white liquor to wood ratio for sawdust is about the same as that for chips in the stationary digesters, even though the cooking time is considerably shorter in the continuous digester. When cooking both chips and sawdust in the continuous digester, the liquor requirement was 30 to 40% higher.

From a study of our sawdust cooking we believe there is only a slight loss in strength by cooking in this continuous digester unit. This is based on comparison with cooks made in the laboratory experimental stationary digester. This loss could be accounted for by the shorter cooking time in the continuous digester. A greater loss was found when cooking

chips in the continuous digester compared to cooking them in the mill stationary digesters. This and the higher amount of active liquor required resulted in a study of cooking all sawdust, instead of chips and sawdust as originally designed. This appears to be the best way to utilize the Pandia continuous digester. Considerable work has been done with rotary valve feeders, on which we are still planning some additional work. The main problem has been in getting proper feeding, which consists mainly of getting the pockets to fill and discharge properly.

CONTINUOUS DIGESTER COOKING SUMMARY

Originally, the digester was operated with only the amount of white liquor required for obtaining the desired permanganate number. Our experience shows that if too much liquid is used in relation to the wood, there is a tendency to wash sawdust past the chamber screws, permitting shives in the stock. If insufficient liquid is used, the mixture apparently becomes mealy and causes increased loading of the conveyors. Although we cannot see in the unit, it is our belief that the best consistency is one which makes the wood and liquor mushy so that it is easily conveyed yet is not wet enough to permit the liquor to separate or flow from the wood. To obtain this condition we have added a black liquor feed which is controlled by experience with the chamber amperage loading.

It is our understanding that The Black-Clawson Corp. has since recognized this same problem and has provided for the adding of an excess of liquid at the entry point. Under the first chamber there is a screen grid built in through which excess liquor may be drained out of the stock and dropped to a tank for recirculating. The white liquor is added on the basis of requirements for cooking, and sufficient liquor is recirculated to maintain stock wet enough to have some drainage in the first chamber.

Of the many advantages to continuous cooking we listed the following.

1. Uniform rate of steam consumption.
2. Uniform rate of discharge, instead of surging as is done in blowing stationary digesters.
3. Less labor required for operating.
4. More uniform cooking.

The main disadvantages have been the additional mechanical equipment and mechanical problems.

The Pandia and related washing system was installed in the new paper mill building away from the pulp mill since it was originally intended to be used only for that machine. It was designed to be operated by two people, one on the Pandia and one on the press washing system. Through proper usage and location of instruments, knowledge gained by operating experience, and the mechanical improvements made, the two jobs have been combined and there is now only one man per shift operating both the Pandia and the brown stock washing system.

Considerable work has been done at the Lewiston mill to improve the Pandia continuous digester operation. It is felt that with continuing efforts of equipment builders and work done in mills, continuous type cooking will eventually replace stationary type digesters. Several new mills have recently started production with continuous type digesters only.

Presented at the meeting of the Pacific Section of TAPPI, held in Longview, Wash., Jan. 19, 1960.

A Temperature Controlled Spent Sulfite Liquor Diversion System

E. A. Woodworth

Unless carefully controlled, industrial and municipal waste materials may exhaust the oxygen content of receiving waters into which they are discharged. This hazard is greatest during summer months when low water levels, high water temperature, and increased bacterial growth further reduce the oxygen supply. Since the spent sulfite liquor contributes approximately 70 to 90% of the B.O.D. demand from the West Linn mill of Crown Zellerbach, it is the logical waste material to divert from the Willamette River. By this diversion, at the right time, the greatest effect can be attained.

E. A. Woodworth, Crown Zellerbach Corp., West Linn, Ore.

In the ponding of spent sulfite liquor it is imperative, because of available storage capacity, that the spent liquor pumped to the storage lagoon contain the maximum possible pounds of B.O.D. per gallon pumped.

It would be possible to attain this control with timers if we could be assured that the blowpits would be empty at the time of each digester blow. But this cannot be, because it is necessary at times to use the individual digester blowpits as additional storage. Originally the spent sulfite liquor diversion system consisted of remotely operated three-way valves, which were manually operated by blowpit personnel. These three-way valves were set to drain for a specified period of time the spent sulfite liquor to storage tanks, then pumped to the storage lagoon.

Another method was to vary the drainage time in order to maintain a specified flow to the lagoon, usually with a set rate in gallons per minute for each month.

Neither method, it was found, would give the desired results for the following reasons: (1) varying blowpit inventory; (2) high lagooning rate, or gallons pumped per pound B.O.D. lagooned; and (3) varying river flow and dissolved oxygen content.

In making a proper approach to the above problems, it was thought necessary to make changes to the system so that the system would be relatively unaffected by the above mentioned conditions. Before installing a new diversion control system it was necessary to find out what happens to the pounds B.O.D. per gallon and the per cent solids of the spent sulfite liquor as it drains from the blowpits at varying blowpit inventories. These tests were taken by the West Linn laboratory and it was found that even for varying blowpit inventories there was a definite relationship between the temperature of the spent sulphite liquor, per cent solids, and pounds B.O.D. per gallon. Therefore a system could be installed that would be relatively unaffected by: (1) varying blowpit inventory; (2) high lagooning rate, or gallons pumped per pound B.O.D. lagooned; (3) varying river flow or dissolved oxygen content.

A diversion system utilizing the temperature of the spent sulfite liquor as it drains from the blowpits was installed in 1958. In this system all but the third variable, namely, the varying river flow and dissolved oxygen content would be controlled automatically. The varying river flow and dissolved oxygen content, which is the reason for the whole system, is compensated for in the changing of the temperature at which the spent sulfite liquor is diverted to the storage lagoon. The most important consideration is given to the dissolved oxygen content of the river water. The river conditions previously mentioned are the determining factors in the per cent B.O.D. reduction required.

The temperature controlled diversion system, as will be later described, makes it possible to predict and attain the desired per cent B.O.D. reduction. From the over-all system operation, we are primarily concerned with: (1) per cent B.O.D. reduction and (2) gallons pumped per pound B.O.D. lagooned (Fig. 1).

The Tel-O-Set temperature transmitters measure and transmit the temperature of the spent sulfite liquor as it drains from the individual digester blowpits to the control panel which is located in the sulfite screen room. Each 3–15 signal (denoting temperature) is connected to its individual diverting relay and to a temperature recorder.

The diverting relays (Honeywell RO48B) control the posi-

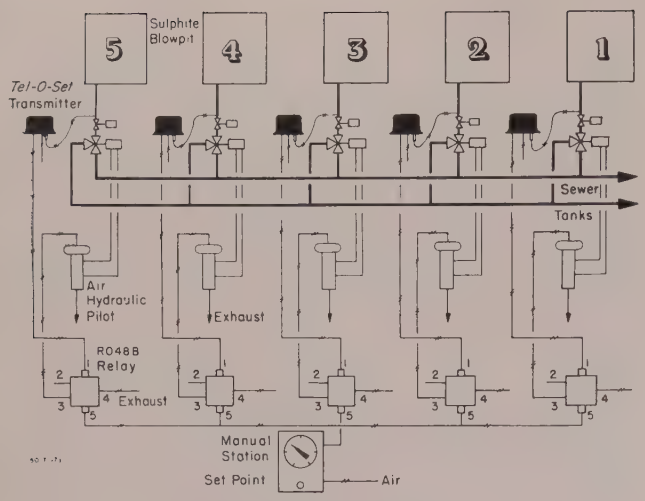


Fig. 1. System diagram

tion of the hydraulically operated three-way valves through DeZurik air-hydraulic pilots. The diverting relays are a pneumatic relay which has the ability to compare two pneumatic signals and to divert or transmit either the higher or lower signals. In this application the diverting relay is used to control an "on-off" air signal to the air-hydraulic pilots. Pressure gages are mounted at connection no. 3 on the diverting relays to indicate control position.

The diverting relays are connected as follows:

Connection no.	
1	3–15 signal from temperature transmitter.
2	Filter air supply (15).
3	Control air to air-hydraulic pilot.
4	Exhaust.
5	3–15 signal from set point manual station.

The temperature set point is a pneumatic manual station, calibrated from 50 to 250°F. over a span of 3 to 15 p.s.i. The 3 to 15 p.s.i. signal from this manual station is connected to port 5 of the diverting relays and determines the temperature at which the spent sulfite liquor is diverted to the storage tanks and then pumped to the storage lagoon. This temperature is determined by the per cent B.O.D. reduction desired.

The DeZurik air-hydraulic pilot valves control the position of each of the five blowpit drain valves upon an air signal from their respective diverting relays. A zero p.s.i. air signal sets the three-way valves to drain to the sewer and a 15 signal sets the three-way valves to drain to the spent sulfite liquor storage tanks.

The temperature of the spent sulfite liquor leaving the blowpits is recorded on two recorders and are used in checking system operation.

The level of the storage tanks is recorded and controlled, and along with recording and totalizing of the spent sulfite liquor flow to the storage lagoon provide the additional records needed for system evaluation. The level control of the storage tanks makes it possible to study blowpit drainage rates at various blowpit inventories.

In Fig. 2 are shown charts of the temperature recordings of the spent sulfite liquor as it drains from the blowpits. These charts are comparable with charts throughout the period of spent sulfite liquor diversion for 1959. The charts shown illustrate the effect of blowpit inventory upon the drainage rate of spent sulphite liquor from the blowpits. Inspection of these charts show the following wide differences.

Date	*Blowpit inventory*	*Maximum temp., °F.*	*Drainage time, min.* 110°F.	150°F.
July 27	High	171	197	120
Sept. 30	Low-Med.	189	86	69
Difference		+18	−111	−51

The charts shown in Fig. 2 confirm the data taken by the West Linn laboratory and also emphasize one of the variables encountered and overcome by the temperature controlled spent sulfite liquor diversion system. From the wide variance in drainage times, for varying blowpit inventories, it can be seen that a system based upon a set drainage time would not achieve the desired results. The only limitation in this respect for the temperature controlled diversion system is at set points of above 175°F. The temperature recording charts have proved a valuable tool in checking system operation. The use of these charts have indicated plugged drains or pumps, which because of the daily check of all these charts, necessary repairs were made without undue loss to the system's efficiency.

Figure 3 shows a graph developed from the West Linn's experience for the period June 20 to Oct. 31, 1959. The curve as presented will be used as a guide for following years operation. The curve is shown as an average maximum per cent reduction guide not taking into account blowpit inventor effects upon system operation at high set point temperatures.

A major factor to be considered is the gallons pumped per pound B.O.D. lagooned. This is extremely important in consideration of the capacity limit of our storage lagoon. Experience shows that if the per cent reduction goes up the gallons pumped per pound B.O.D. also goes up. The advantage of the temperature controlled system is evidenced here in the fact that we are able to predict and attain the desired per cent

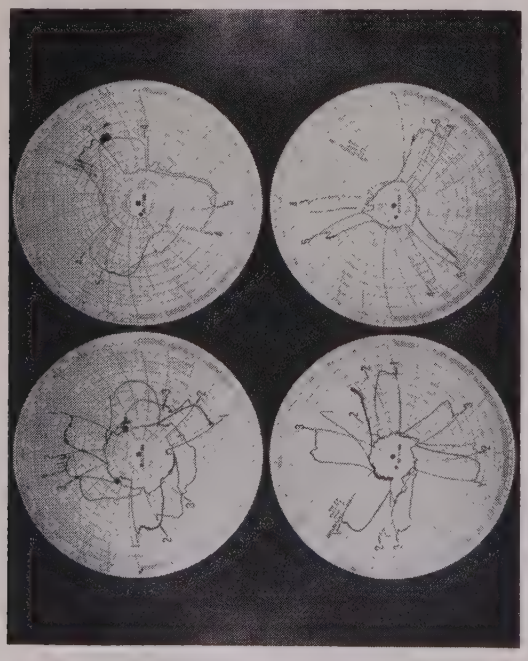


Fig. 2. Temperature recording charts

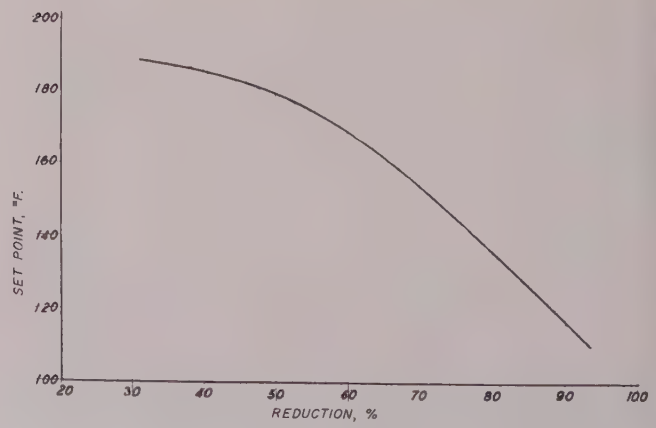


Fig. 3. B.O.D. reduction per cent vs. temperature

reduction at the lowest possible gallons pumped per pound B.O.D. lagooned.

RESULTS

At the start of spent sulfite liquor lagooning in 1952, the original system operated at a lagooning rate of about 8.0 gal. pumped per lb. B.O.D. lagooned. In 1958, the first year of operation of the temperature controlled diversion system, we operated at a lagooning rate of 5.67 gal. pumped per lb. B.O.D. lagooned. Prior to the 1959 lagooning season, new T-316 stainless steel three-way valves were installed in the blowpit drains. The 1959 lagooning rate which dropped to 4.65 gal. pumped per lb. B.O.D. lagooned (a decrease of 22% under the 1958 experience) justified the new three-way valve installation. This increase in system efficiency is surprising, but points out that any system is only as good as the efficiency product of all components.

Comparing results obtained in 1959 versus 1952 on a per cent reduction basis, we find in 1952 a reduction in the B.O.D. demand from spent sulfite liquor of 83%, and in 1959, 66.7%. It would appear from these figures that the temperature controlled spent sulfite liquor diversion system was not doing a good job, but this is not true. The facts are that in 1952 it took 8.0 gal. pumped per lb. B.O.D. lagooned and in 1959 it took only 4.65 gal. pumped per lb. B.O.D. The 1959 per cent reduction would have been much higher, but in the month of October river flows and oxygen content were such that we operated at a low per cent reduction. Consequently, high temperature diversion set point and low gallons pumped per pound B.O.D. lagooned. Using the 83% reduction figure and curves developed from our 1959 operation, it would be possible to do this and yet attain a lagooning rate of 4.95 gal. pumped per lb. B.O.D. lagooned. This projected lagooning rate is 60% less than in 1952, a significant difference. This projected lagooning rate is assumed at a constant set point of 130°F., but this is not possible since at times we are required reduce the B.O.D. load more than the 83% reduction.

In 1959 the lowest diversion temperature used was 105°F. at which set point we were able to attain an average per cent reduction of 93.2% with a lagooning rate of 5.5 gal. pumped per lb. B.O.D. lagooned. The temperature controlled spent sulfite liquor operated as expected and the over-all system efficiency was good. The only limiting factor being high blowpit inventories at high diversion temperatures. The present system was proved very versatile and affords us the exacting control of spent sulfite liquor B.O.D. diversion as required by river conditions.

Presented at the meeting of the Pacific Section of TAPPI, held in Longview, Wash., Jan. 19, 1960.

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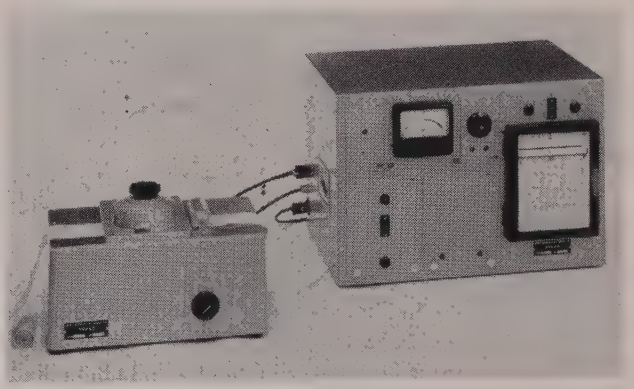

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Process Understanding Required for Systems Engineering

JOEL O. HOUGEN

Some of the principal factors which must be resolved before systems engineering concepts can be reduced to practice are discussed using examples taken from experiences in the chemical industry. The importance of experimental work and methods of collecting and interpreting data is stressed, and illustrated with actual case studies.

In recent years a vast body of knowledge has accumulated pertaining to systems engineering in areas outside the chemical industry. Currently, however, the chemical industry is being stirred to action so that similar information is beginning to be generated in this area of activity and a sort of technical renaissance seems to be in the making.

A growing number of chemical engineers are becoming convinced that profitable results can be obtained through the application of the principles of systems engineering and a few companies have seen fit to organize groups of men, similarly inclined, for a systematic attack on problems amenable to solution by these newer techniques.

In order to clearly state the objectives of this paper, it is first necessary to define systems engineering. It shall be implied that it is the use of all such properties of physical systems and associated mathematical and experimental techniques and tools needed to produce a processing entity or plant with predictable steady state and dynamic behavior. Thus those areas included in the statistical realm or in operations research are excluded from our discussion, nor are digital control techniques included although such work often fits into a systems engineering organization. It is intended herein to confine our attention to those facets of technology and theory with which an engineer must be fully conversant before successful systems engineering, as above defined, can be accomplished effectively.

The problems generally encountered by chemical engineers may be characterized almost always as difficult and of these it is usually the most difficult which are presented to the systems engineer. Processing problems have this character because of the multiplicity of phenomena which are usually involved and the uncertain nature of most of these phenomena. Thus mixing, in vessels or conduits, which is present in so many processes is inherently a subtle combination of mechanisms with end results highly dependent on geometric configuration. The same may be said of heat transfer and chemical reaction. Yet problems in which these are involved are the daily diet of chemical engineers in the process industries.

Before attempting to achieve an understanding of processes, it is necessary that the prospective systems engineer understand fundamental concepts. But this is not enough. He must also be equipped with a substantial knowledge of experimental techniques and methods of interpreting data. The acquisition of the necessary background presents a serious problem to the practicing engineer.

Joel O. Hougen, Monsanto Chemical Co., St. Louis, Mo.

Any company wishing to organize work in this area with engineers inexperienced in such work would find it profitable to embark first on a serious education and training program. Part-time effort is sure to be rather ineffectual and ultimately excessively time consuming and expensive. An educational program used by Monsanto Chemical Co., which has been very successful in imparting the requisite knowledge, has been described in the literature (*1*) and will serve as an example of a determined effort to create a group of qualified engineers.

The fundamental training which seems most useful should include the following material:

1. Mathematics, including differential equations, complex variable and boundary value problems.
2. Servo theory and transient analysis.
3. Computer application, both analog and digital.
4. Refresher courses in chemical processing principles, thermodynamics, kinetics, and fluid mechanics.
5. Training in experimental methods, data reduction, and analysis and practice in problem formulation.

A minimum of a year and one half, full time, should be allowed for the average graduate chemical engineer to acquire the proper understanding of these basic tools.

How are these tools applied in gaining an understanding of processes?

Reduction to practice seems to proceed somewhat as follows: First, there is an effort to develop a theory describing the physical situation; second, comes a period devoted to experimentation or data collection. Then, in the light of the theory, data are interpreted and correlated. At this stage, if all has gone well, it is desirable to generalize the conclusions in order to extend or extrapolate the correlations and thus expand their usefulness.

Frequently steps one and two occur simultaneously; at other times step two occurs before a satisfactory theory is developed. As a matter of fact, adequate theory may never be forthcoming so that one may be required to rely solely on observed data. Interpretation and generalization then become uncertain and limited. Additional information may, in any case, also be required in order to improve or verify the generalizations.

I believe what most of you would like to know is how one acquires an understanding of process dynamics sufficient to use the information in an intelligent and useful way. First, let me say that I know of no case where a plant, or even one portion of a plant, has yet been designed using a substantial amount of dynamic information. We have not yet acquired enough of such data. But I have no doubt that the years ahead will see a rapid increase in the demand for such information and a very determined use thereof, and of course most of the really significant work is proprietary in nature and is never published.

DATA COLLECTION, INTERPRETATION, AND APPLICATION

To illustrate the several facets of data collection, interpretation, and application, let us construct a problem. Suppose we wish to continuously blend a solute-containing solution with a diluent solvent in order to get a homogeneous solution of a given concentration at a substantially constant rate. Furthermore, suppose we wish to consider the use of a sec-

tion of straight conduit with a circular cross section for this blending operation.

Immediately we need to know the response of this mixing system to changes in concentration and flow rate. Procedures in a well-ordered attack on this problem might be as indicated previously.

Develop the Mathematical Model

A comprehensive model accounting for molecular diffusion and axial mixing is given as:

$$\bar{D}\left[\frac{\partial^2 C}{\partial r^2}+\frac{1}{r}\frac{\partial C}{dr}+\frac{\partial^2 C}{\partial x^2}\right]=\frac{\partial C}{\partial t}+\frac{u\partial C}{\partial x} \qquad (1)$$

It may be reasoned, however, that it would be impractical to consider radial gradients in concentration in pipes or tubes. Moreover, if turbulence exists, as would be desirable, molecular diffusion $\bar{D}$ is negligible compared with eddy diffusion. Accordingly, as a proposed model, we arrive at the form:

$$D\left[\frac{\partial^2 C}{\partial x^2}\right]=\frac{\partial C}{\partial t}+\frac{u\partial C}{\partial x} \qquad (2)$$

Where D is an effective or apparent diffusion coefficient. This latter form may be derived by extending Fick's law for molecular diffusion by allowing for the axial motion of the fluid stream and permitting D to include molecular and eddy diffusion.

The solution to this partial differential equation depends on boundary conditions and these, in turn, depend on experimental conditions. It is thus necessary to choose those which are both convenient experimentally and theoretically.

Design Experimental Procedures

Some kind of tracer technique is suggested to follow the mixing or dispersion phenomenon in a tube. Furthermore, in order to conserve solute as well as to keep system changes to a minimum, a pulse type of testing procedure appears attractive. In this method, a rather sudden change in solute composition of the stream is made and changes in concentration caused thereby measured at various positions along the tube, downstream of the disturbance.

If the disturbance is considered to be an impulse (a pulse of infinite strength and zero width), the solution at any position and time is given as:

$$C(x,t)=\frac{1}{2\sqrt{\pi Dt}}\,e^{-\frac{(x-ut)^2}{4Dt}} \qquad (3)$$

This form of response being experimentally verified by G. I. Taylor (*2*).

Since impulse forcing may be difficult to effect in this case, the more general solution with an arbitrary pulselike function of time $F(t)$ as the input is desired.

The following conditions are realizable:

$C(x, 0) = 0$
$C(\infty, t) = 0$

and

$C(0, t) = F(t)$.

The solution in terms of the operator s becomes:

$$C(x,s)=f(s)e^{\frac{ux}{2D}\left(1-\sqrt{1+\frac{4Ds}{u^2}}\right)} \qquad (4)$$

Where $f(s)$ is the Laplace transform of the input time function, $F(t)$.

Now suppose we form the ratio of the above solution corresponding to two positions along the tubes, each relative to the same input and then let $s=jw$. It will be noted that $f(s)$, being common to both equations, will disappear and we are left with an expression in terms of frequency which will be termed the theoretical performance function(PF):

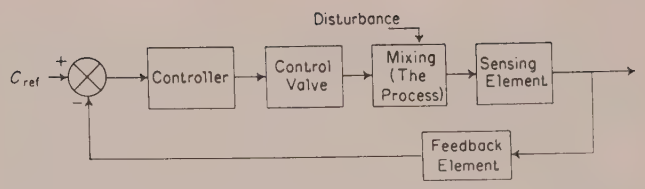

Fig. 1. Block diagram representation of process and control elements

$$[\mathrm{PF}]_{\text{theoret.}}(jw)=\frac{e^{\frac{ux_2}{2D}\left(1-\sqrt{1+\frac{4Djw}{u^2}}\right)}}{e^{\frac{ux_1}{2D}\left(1-\sqrt{1+\frac{4Djw}{u^2}}\right)}}=e^{\frac{u(x_2-x_1)}{2D}-\frac{u(x_2-x_1)}{2D}\sqrt{1+\frac{4Djw}{u^2}}} \qquad (5)$$

This latter frequency function can be written in an equivalent amplitude and argument form:

$$[\mathrm{DAR}]_{\text{theoret.}}(jw)=e^{\left[(x_2-x_1)\frac{u}{2D}\left\{1-\left(\frac{4Dw}{u^2}\right)^2\right\}^{1/4}\cos\alpha\right]} \qquad (6)$$

$$[\mathrm{DRA}]_{\text{theoret.}}(jw)=(x_2-x_1)\frac{u}{2D}\left\{1+\left(\frac{4Dw}{u^2}\right)^2\right\}^{1/4}\sin\alpha \qquad (7)$$

$$\text{where } \alpha=\frac{1}{2}\tan^{-1}\frac{4Dw}{u^2}$$

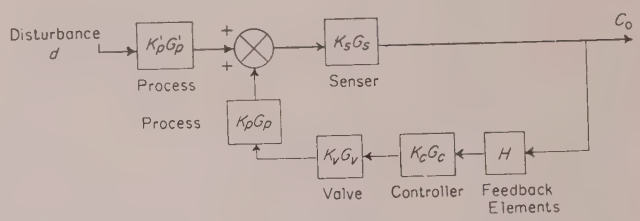

Fig. 2. Block diagram representation of process and control elements

And thus we have expressions in familiar "frequency response" form. From these relations, equivalent dynamic amplitude ratios (DAR), and dynamic response angles (DRA) can be computed for various combinations of the system dimensions, $(x_2 - x_1)$, flow condition, u, and parameter, D.

Verify Theory Through Analysis of Data

It merely remains to collect experimental data and reduce it to frequency response form in order to compare results with theory. In this case, however, we may not have an independent evaluation of the effective diffusion coefficient, D, so the object may be to determine this by comparing theory and experiment hoping to find consistent values of D.

To effect this, the results of pulse testing are processed to give the ratio of Fourier transformations from which a corresponding dynamic amplitude ratio and dynamic response angle are computed. Thus the performance function computed from pulse testing is:

$$[\mathrm{PF}]_{\text{exptl.}}(jw)=\frac{\int_{-\infty}^{\infty}e^{-jwt}f(t)_{\text{out}(x_2)}dt}{\int_{-\infty}^{\infty}e^{-jwt}f(t)_{\text{in}(x_1)}dt}=[\mathrm{DAR}]_{\text{exptl.}}(jw),\ [\mathrm{DRA}]_{\text{exptl.}}(jw) \qquad (8)$$

Computation procedures are outlined by Draper, McKay, and Lees (*3*) and numerous applications have been described (*4–7*). A high-speed digital computer is mandatory for reducing the data.

Generalize the Results

Having examined data for a wide range of system variables, it will be assumed that a more or less generalized correlation between D and, say, Reynolds number can be found, thus placing us in a position to predict variations in concentration in response to changes in the influent stream in mixing tubes of various sizes. At this point it may be said we have an adequate understanding of the process in question, for we can, with confidence, predict the transient change in average composition at any distance along a mixing tube which occurs in response to an arbitrary change in composition of the influent stream.

Application—Design of Control System

The next logical development in the application of the systems engineering approach is to design the requisite control system. Some of the problems encountered and areas where understanding is needed will be pointed out.

A simple, single-loop control system which might prove satisfactory is illustrated in Fig. 1. This arrangement is typical of those using feed forward compensation if variations in $C_{ref.}$ are to be handled.

However, if $C_{ref.}$ is held constant and disturbances are to be controlled, feedback compensation is involved. A more conventional diagram using literal symbols is shown in Fig. 2. A performance function of interest in this case becomes

$$\frac{C_o(jw)}{d} = K_p'G_p' \left[\frac{K_sG_s}{1 + K_pG_pK_vG_vK_cG_cH\ K_sG_s} \right] \qquad (9)$$

This relates the changes in outlet concentration, C_o, to the disturbance, d. The diagram indicates that the response of the process to a disturbance is added to that due to the corrective action, the sum being measured by the sensing device. Because of the negative feedback arrangement, the sum is actually a difference, the corrective action tending to nullify changes generated by the disturbance.

Thus assuming a constant control point with disturbances as the input, we are led to the conclusion that in order to suppress the effects of the disturbances, the denominator of the performance function, $C_o(jw)/d$, should be very large over a reasonable frequency range.

On the other hand if we treat the disturbances as constant and consider the responses to changes in control point, $C_{ref.}$, we find that

$$\frac{C_o}{C_{ref.}} = \frac{K_cG_cK_vG_vK_pG_pK_sG_s}{1 + K_cG_cK_vG_vK_pG_pK_sG_s\ H} \qquad (10)$$

In this case we wish to have this ratio remain substantially equal to unity over an acceptable frequency range.

The problem is to choose components represented by K_cG_c, K_vG_v, K_sG_s, H such that the magnitude of changes in C_o are held within bounds at all times and that, following a disturbance, or change in control point, the controlled concentration returns to an acceptable steady value as quickly as possible.

The criteria suggested by both performance functions must be satisfied, within limits, by making reasonable compromises.

The difficulties involved in achieving this may be rather formidable. One difficulty arises because of the likely nonlinear behavior of the control valve represented by the symbol K_vG_v. Whereas the frequency dependent part, G_v, might be approximated by a linear form such as

$$\frac{1}{(s^2 + 2\varphi w_n s + w_n^2)}$$

the K_v factor generally depends on the pressure drop available at the valve. Valves are characterized by their flow-lift relations at given constant pressure drops. Unfortunately, as flow increases, the available pressure drop for the valve decreases both because of increased friction losses in lines and apparatus and a diminution in supply pressure be it from pump or main.

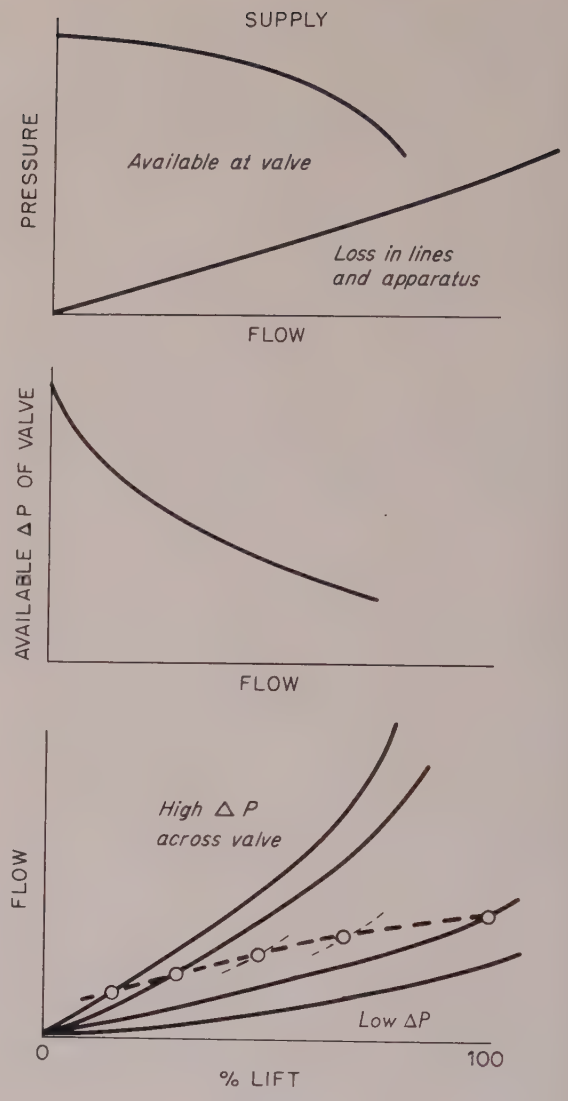

Fig. 3.

The situation can be illustrated in Fig. 3.

In the last diagram the points correspond to the flows obtainable at given pressure drops for the particular system. The line through these points gives the flow-lift characteristics of a specific valve in a specific installation. The relation is not necesarily linear, the sensitivity K_V being the slope at the point in question.

To remove nonlinearities arising from variations in K_v, compensation could be introduced by using a nonlinear valve positioner (which in the block diagram might be included in K_c) or by proper selection of H, the feedback component.

Another source of difficulty lies in the sensing element represented by K_sG_s. If composition is measured by potentiometric or optical methods, a nonlinear relation between concentration and signal exists. This means that the sensitivity of the sensing element, K_s, varies with concentration. This relationship must be known and, if required, compensated by an added component such as that shown by H.

Finally there is the problem of selecting the control components and adjustments so the desirable closed-loop response is obtained. If the system has been linearized, the procedure of determining what is required follows along rather conventional lines, graphical techniques frequently being the most satisfying. Difficulties arise in finding components which will perform in the desired manner. In addition, the adjustments of the controller must be correlated with the parameters of the mathematical model or graphical representation of it.

A complication arises when significant delay times exist any place in the system such as in pneumatic transmission lines, motor valves, or the process itself.

All these realities of life must be understood and appreciated before system design can be completed in a quantitative manner. Having done so, one is assured of a processing system properly scaled up and an associated control system capable of maintaining its performance within prescribed tolerances.

As is obvious, a large amount of both experimental and theoretical work is required in order to gain the necessary understanding.

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Computer Control in the Pulp and Paper Industry

T. M. STOUT

The digital control computer is a new tool which may prove useful in the pulp and paper industry as a supplement to conventional instrumentation. Capable of dealing rapidly and consistently with complex relationships, the computer finds application to processes meeting several obvious technical and economic criteria. These requirements include frequent disturbances, conflicting objectives, numerous interrelated variables, and a potential for dollar gains which can justify the investment in new equipment. A computer can be used in several ways: as a data processing device which receives signals from process instruments and presents computed values for use by an operator, as a sequence controller which obtains most of its data from an operator and then exercises direct control over the process, or as a full-fledged controller which notes process conditions and takes action without operator intervention. Diagrams are included to show how a computer is integrated with process instruments and how its various functions are programmed. Design of a computer control system is a difficult task which requires identifying process boundaries, stating process objectives in economic terms, developing control relationships, investigating instrumentation problems, and working out procedures for normal and special operating conditions. Developing control relationships is the hardest part of the job. The equations needed by the computer can be derived from past operating data, from theoretical considerations, or—preferably—from a combination of data with theory. These steps have been carried out successfully in other industries. With recent advances in the technology of pulp and paper, it seems probable that the problems can be solved in this industry as well.

Paper manufacturers do not need to be reminded of the long history of their industry, the continuing evolution of process equipment and control techniques, or the growing pressures for new and better products, for more efficient use of raw materials and recovery of wastes, and for general reductions in operating costs. Nor should a neophyte presume to offer any ready-made solutions to these pressing problems. However, it may not be out of place to discuss a new control device—the digital control computer—which has found applications in other industries and which might prove helpful in connection with the problems facing the pulp and paper industry.

Computers for business and engineering use are now commonplace, and their capabilities are widely appreciated. The use of smaller, specially designed, general purpose computers for process control is relatively new. In systems now being planned and installed, these computers receive data from process instruments, perform calculations to determine the best operating conditions, and transmit the results as set points to conventional controllers. A natural step in the evolution of process instrumentation, the control computer offers the hope of further improvement in plant operation.

This paper attempts to enhance the understanding of computer control systems by explaining their operation, listing typical cost figures and discussing the justification for such expenditures, enumerating the steps to be carried out in system design, and suggesting some applications in pulp and paper manufacture.

COMPUTER CONTROL SYSTEMS

Computers can assist in process control in a number of ways but not all of the applications can be called "computer control systems." Shown schematically in Fig. 1–4, the possible approaches range from periodic off-line calculations to continuous closed-loop control.

An off-line application of a computer is shown in Fig. 1. Here information from process sensing devices is collected by an operator and supplied to the computer through digital input devices (such as punch card or tape readers). The computer results are presented to the operator by a typewriter (or equivalent means) for his use in adjusting control devices in the process. This approac his suitable where process relationships are relatively complex but process conditions need only infrequent adjustment.

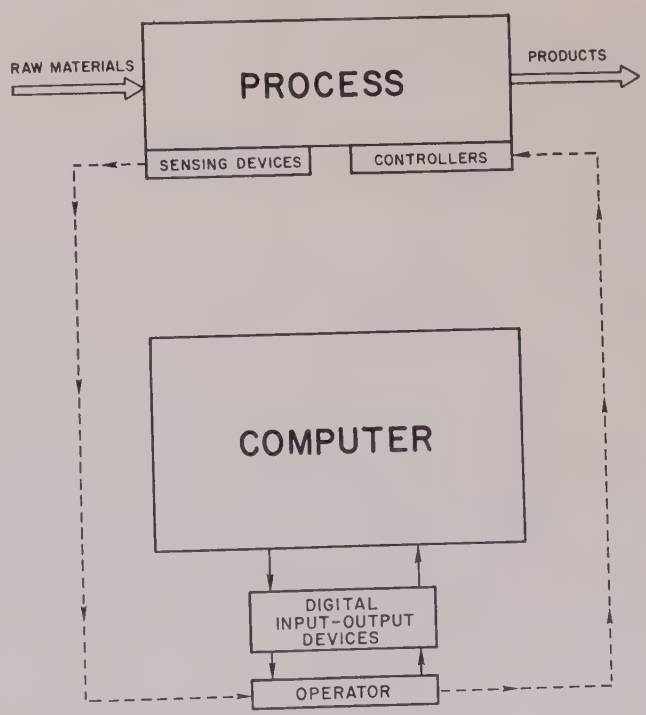

Fig. 1. Computer used for off-line control calculations

T. M. Stout, the Thompson-Ramo-Wooldridge Products Co., Beverly Hills, Calif.

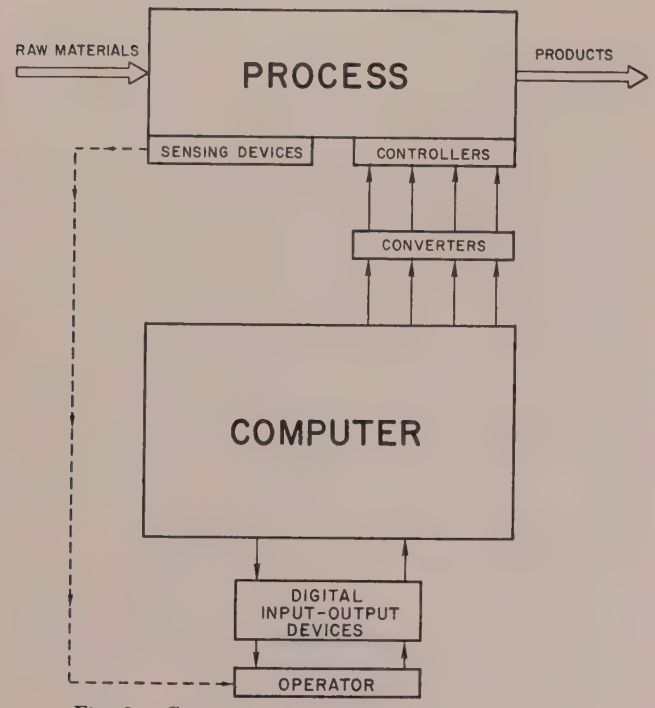

Fig. 2. Computer used as sequence controller

Use of a computer as a sequence controller is illustrated in Fig. 2. In this application, the computer receives its information from an operator who observes raw material characteristics, product specifications, and the condition of process equipment and wishes to set process conditions accordingly. This approach might be used in computer control of batch digesters, where the computer might be substituted for the present cam-actuated controllers. Means would be provided by which the wood species and degree of cooking desired could be communicated to the computer. With this information, the computer could refer to its memory for the proper weights of chips, black and white liquor, and it could transmit signals to control charging of the digesters. It could also select a time-temperature-pressure program and control the steam flow and relief valves. This approach requires a minimum number of process measurements, but it does not fully utilize the capabilities of the computer.

A computer used as a data logger and operating guide calculator is shown in Fig. 3. Process sensing devices are connected, through converters which change the original signals into a form acceptable to the computer, directly to the computer in this system. The computer outputs are raw process data or functions of the original readings, such as yields or efficiencies, which may help the operator to adjust the process to a better set of conditions. This approach is useful when process relationships are being established but contains many of the deficiencies of conventional control schemes.

A closed-loop computer control system is shown in Fig. 4. In a system of this kind, the computer reads process instruments, calculates the best operating conditions, and resets the process controllers automatically. In normal operation, the operator receives data on performance of the process-computer system via a typewriter or special signaling devices and can modify system operation by inserting new constants or complete programs via a tape reader, switches, or other input devices. In emergencies, the operator can assume control, running the process in the same way as before installation of the computer.

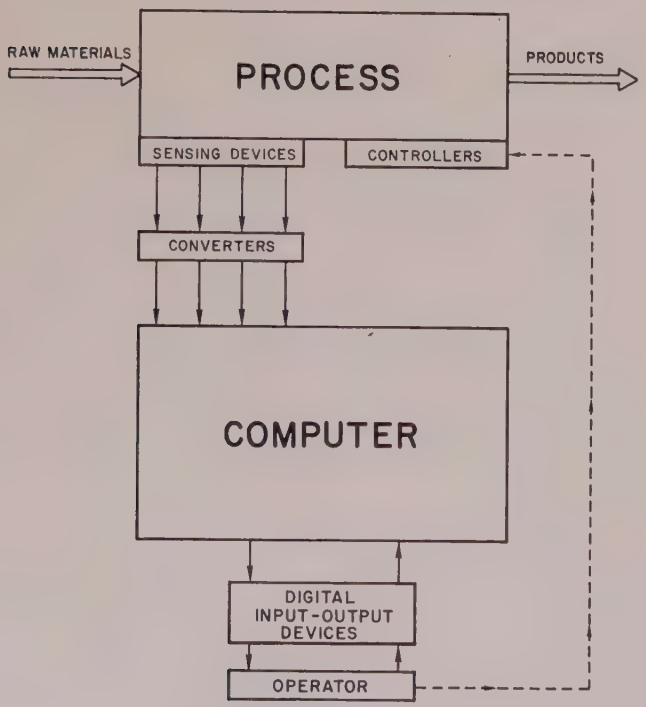

Fig. 3. Computer used as data logger and operating guide calculator

OPERATION OF COMPUTER CONTROL SYSTEMS

Computer control systems may employ analog or digital computers and may operate in either of two general modes. In one type of system, the computer is programmed to carry out experiments on the process: one of the variables is changed slightly; after a suitable delay, the result is noted; and further changes are made in a direction which has a favorable effect on process performance. Where many variables are involved, a sequence of changes is made, observing and recording the results of the change in each variable so that favorable changes can be made on the next cycle. In another type of system, the computer is provided with equations representing the process and, in effect, conducts experiments on a mathematical model of the process. The search procedure used with a mathematical model to locate the best operating conditions is quite similar to that employed in experimenting on the process itself, but it can be completed more quickly since the normal process time lags are not encountered. Another difference is found in the fact that com-

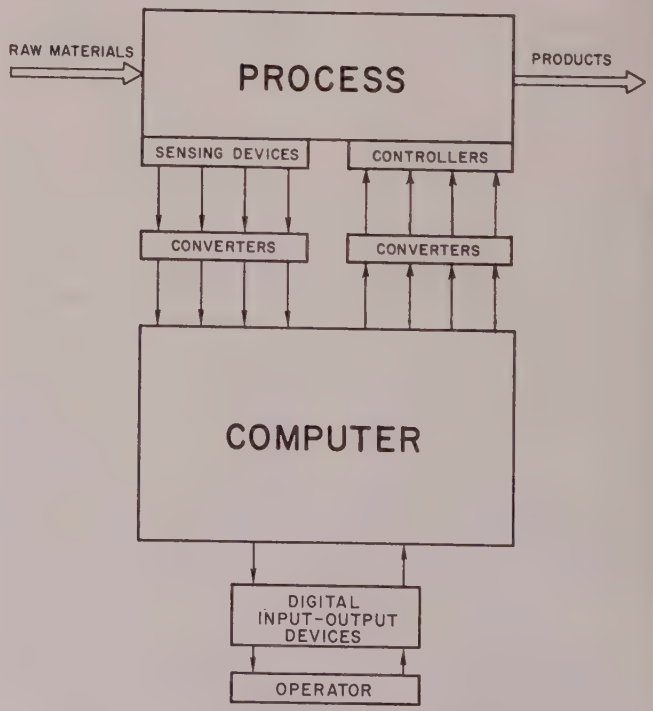

Fig. 4. Computer used for closed-loop control

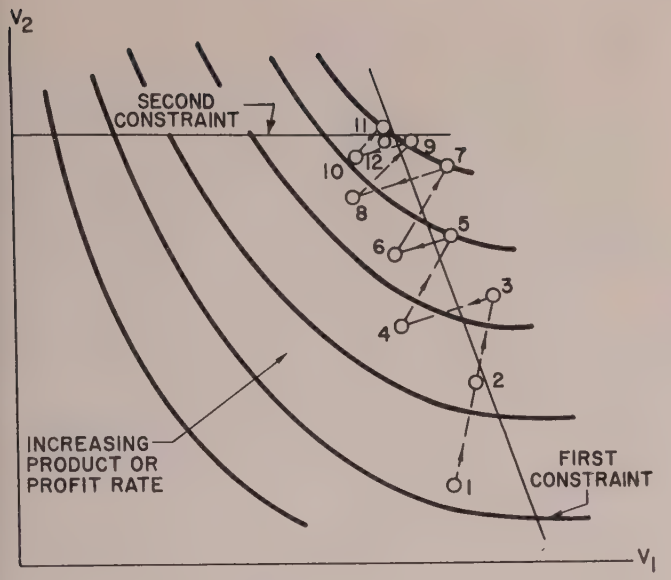

Fig. 5. Optimization in two variables with constraints

binations of process variables which would violate constraints can be examined by the computer, as suggested in Fig. 5, in the course of its control calculations. These combinations are never imposed on the process and hence cause no difficulties.

A computer system employing a mathematical model could be used to control operation of batch digesters in either of two ways. In the simpler of the two schemes, the computer would be expected to develop the cooking cycle from a set of basic equations. These relationships, developed from past operating data, might express such properties as yield, strength, and bleachability as functions of wood species, liquor ratio, chemical-to-wood ratio, temperatures and pressures at various points in the cooking cycle, and the controllable parameters of the cooking cycle. In effect, the "best" cycle for each charge would be interpolated from equations summarizing practices which have proved successful in the past. Unlike the cam-actuated controllers, a computer used in this manner would provide an unlimited variety of cooking cycles, each tailored to an individual digester charge.

In a more sophisticated approach, the computer would be provided with information on the progress of the reaction(s) periodically during the cooking cycle. By means of some approximate kinetic equations, containing rate constants which are modified to fit the observed history of the cook, the computer would determine the future program of pressure or temperature variation needed to reach the desired pulp characteristics in minimum time or at minimum cost. It might also control addition of liquor during the cooking cycle. The necessary observations and calculations would be repeated at, say, five-minute intervals. The last approach has been successfully applied in a laboratory-scale research program (*1*). Eckman, Lefkowitz, and their associates at Case Institute developed the measurement and computation techniques needed for control of a batch hydrogenation process. By varying the reaction pressure, in accordance with the general scheme described above, the time required to reach a desired product composition was reduced from 208 to 160 min.

Control systems employing digital computers usually combine the functions of optimization, logging, and sequence control. The various functions are executed in turn under the direction of a program of the kind sketched in Fig. 6. In effect, the computer continually traverses the outside loop, watching a clock and comparing the actual time with the scheduled time for the performance of each function. When the time comes, the computer leaves the main loop, performs the appropriate calculations, resets the time at which the particular function should be repeated, and returns to the

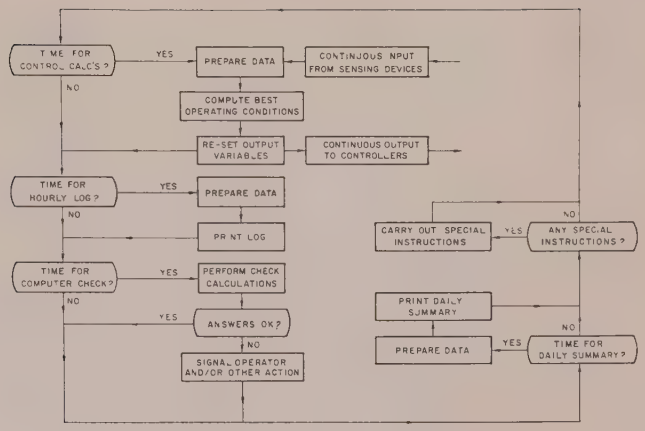

Fig. 6. Diagram of a control computer program

main loop. The control functions generally require more time than the other functions and can be carried out in parts to allow frequent scanning for hazardous conditions. At intervals, the computer can prepare hourly or daily logs, check its own performance, or carry out special instructions. Among the special instructions can be included calibration of instruments and start-up or shutdown of process equipment. These sequencing operations can be programmed if computer capacity is available and if necessary measuring and control points are provided.

Computer control systems of the kind shown in Fig. 4 are valuable when process changes occur so frequently *and* the adjustments and decisions to be made depend on such complex relationships that a human operator cannot respond correctly in the time available. Random disturbances are inevitable: raw material characteristics, chemical compositions, equipment efficiencies, ambient conditions, and product specifications change from time to time. In processes of any complexity, numerous technical relationships—usually understood only in part—and conflicting objectives make it difficult or impossible for any operator to achieve continuously the kind of performance he might be able to realize occasionally. A technical basis can be found for using a control computer in such cases, but it is also essential that dollar benefits be available which will justify the proposed installation.

ECONOMIC JUSTIFICATION

The cost of a computer control system might be as follows:

Computer	$100,000
Input-ouput equipment	40,000
New instruments	40,000
Process modifications	50,000
Engineering	50,000
Total	$280,000

The actual cost depends on the number of computer inputs and outputs, the number of new instruments required, and the amount of process modification necessary to make effective use of the computer. Despite uncertainties in individual items, the estimate of total costs is representative of several actual systems. Its size suggests that careful thought will be given to the advisability of proceeding with an installation of a computer control system.

As with any process improvement, the justification for installing a computer control system is found in better operation, measured in turn by increased production, higher yields, better control of product quality, or reduced raw material and utility costs. In order to see where the necessary earnings can be found, estimated costs for a kraft pulp and paper mill can be examined. For a mill producing 100,000 tons of paper per year, the variable costs would be approximately as shown in the following table.

A 1% reduction in all of these items, brought about by improved control techniques, would save 48,000 dollars per

Wood	$2,750,000
Pulping (chemicals and fuel)	300,000
Bleaching (chemicals and steam)	1,000,000
Fillers, sizing, etc.	500,000
Papermaking (steam)	250,000
Total	$4,800,000

year. A 3% reduction would save 144,000 dollars per year, enough to recover the estimated investment of 280,000 dollars in 2 years.

Of course, the expected earnings of a computer control system cannot be estimated without a detailed investigation. The figures presented above are meant to suggest only that fairly modest reductions in fiber losses, pulping and bleaching chemical consumption, additive requirements, fuel and steam usage could be sufficient to justify a computer control system.

SYSTEM ENGINEERING

Planning a computer control system involves several main steps: (1) fixing process boundaries; (2) specifying process objectives; (3) developing relationships which describe process behavior; (4) stating constraints on process operations; (5) devising an optimization procedure; (6) solving instrument problems; and (7) evaluating the proposed system. Each of these steps involves a number of substeps which deserve separate discussion.

Fixing Process Boundaries

The initial limits for a system design may coincide with the geographical boundaries of the process, but they may later be narrowed to specific parts of the process or expanded to adjacent processes. In a paper mill, the whole mill should be studied initially, and both technical and economic factors should be considered. In this manner, a number of serious mistakes will be avoided. The control computer will not aim for increased production from one part of the mill if downstream processing units cannot handle the additional material. The objective will not be lower costs in one stage of the process if disproportionately greater costs would then be incurred in subsequent stages. Nor will greater mill output be adopted as the goal if the market cannot absorb more product.

While the mill must be viewed as a whole in establishing objectives for computer control of any of its parts, the control problems in the various sections of a mill can often be treated separately. This possibility arises in part from the widespread use of storage tanks and bins between the important processing units. Although longer-term averages of product quantity and quality are coordinated, independent control systems are employed successfully. Where technical and economic considerations dictate some coupling of the various process steps under direction of a single control computer, the computer can still be regarded as having sections of its program devoted to individual units.

The necessity for a careful consideration of process boundaries can be seen from a look at the problems encountered in control of a pulping operation. Looking at the digesters without regard for the rest of the mill, it might appear desirable to increase pulp output, possibly by reducing the time of the cooking cycle. In practice, however, a significant increase might or might not be attainable. Any appreciable increase in digester output would place a heavier load on the recovery system. Depending on its capacity, the recovery system might or might not be able to handle the extra load. The choice of operating conditions is therefore a compromise between income and expense, high production rates ultimately being balanced against greater chemical losses. These factors have been studied by C. W. Carroll (*2*).

Specifying Process Objectives

Processes are designed and operated to produce a profit. Although governed by economic considerations, control objectives for a given process can usually be expressed in more direct ways: a specific or maximum rate must be realized; product quality specifications must be met; waste of fuel, water, and materials must be minimized; and conditions leading to equipment breakdowns, lost production, and unexpected maintenance costs must be avoided.

Process objectives are frequently numerous and contradictory. For example, some of the considerations governing operation of the digesting-washing-recovery system are as follows:

1. The chip-to-liquor ratio, chemical concentration, and other conditions in the digesters should provide as low a lignin content in the pulp as possible consistent with good cellulose yields;
2. The ratio of black liquor recycled directly to the digesters to that processed through the recovery system should give the proper chemical concentration in the digesters;
3. Increased water rates to the washers and causticizing stages provide cleaner pulp, greater liquor recovery, and better causticizing but add to the energy requirements for evaporation and to the direct water cost;
4. Evaporation should be carried far enough so that the liquor burns readily but not so far that it is difficult to handle;
5. Steam production should be adequate to meet the needs of the digesters and other mill requirements;
6. Chemical losses are a potential cause of air and/or stream pollution as well as a direct expense.

Profit, defined as the difference between product value and operating costs (including raw material and utilities), can be used as a single, all-encompassing objective for a computer control system with product specifications, equipment capacities, and safety requirements regarded as constraints defining the permissible region of operation. In order to write a suitable profit function, the system engineer needs some data on material values and operating costs. It is particularly important that he have realistic information on those costs which vary with the way the process is operated. Fixed costs such as administrative charges' overhead, taxes, insurance, and advertising expense charged to the process generally will not concern him if they are truly independent of operating conditions.

Developing Relationships

An important and difficult aspect of any system design is the development of relationships between the process variables. These relationships can represent steady-state or dynamic behavior but must be adequate for prediction of process performance as the independent, controllable variables are changed. These relationships can be theoretical or empirical, but they are best developed by a combination of theory and operating data. Theory indicates what variables are involved and the form of the functional relationships, while operating data permit evaluation of parameters which are not easily fixed by theory. Such parameters can be updated from process measurements by the control computer after it is placed in operation.

Processes for the manufacture of pulp and paper present some formidable problems in this area. Knowledge of the fundamental chemistry of batch digester operation is growing but may still be inadequate; a wealth of empirical data is available, however, which might serve as a starting point for design of a computer control system. The kraft pulping process has been studied by Carroll from a point of view similar to that of the computer control system designer (*2*). Continuous digesters, now becoming more important, are perhaps more easily instrumented and studied (*3*, *4*), and they may be a better candidate for computer control than the older batch digester.

Work on the effects of paper machine variables by Taylor (*5*), Burkhard and Wrist (*6*), Ingmanson (*7*, *8*), and others has done much to put recognized interrelationships on a quantitative basis. As a result, the paper machine may be the logical place to introduce computer control into the pulp and paper industry.

Stating Constraints

As mentioned above, the values of the process variables are affected by product quality specifications, equipment capacities, raw material availability, safety requirements, and other considerations. Optimization of process operation must be accomplished within these restrictions or constraints, typically stated as upper or lower limits on process variables or functions of these variables. Some of these limits are relatively arbitrary and can be written without any difficulty, but others may require considerable effort.

Devising an Optimization Procedure

The word "optimum" means the best that can be done at any given time with the tools available. Optimum process operation is realized by using that combination of variables which maximizes the profit rate and satisfies the constraints discussed above. Development of an optimizing procedure leads the system designer to use of such mathematical tools as ordinary calculus, gradient methods, linear programming, calculus of variations, and dynamic programming.

Solving Instrument Problems

In devising an optimization procedure, the system designer determines which variables are measured and which are controlled. If he has not already done so, the designer must ascertain that variables essential to the control scheme can be measured. Where suitable instruments are not available, alternate means of obtaining the required data must be considered.

Many of the measurements needed in paper mill applications—flow, level, temperature, pressure, speed, and pH—are routine. Other measurements—consistency, basis weight, thickness, and moisture content—have not reached such a high state of perfection. The difficulty with some of the instruments for these variables may be a lack of linearity or a tendency to respond to several variables other than the one desired. Consistency measurements are a good illustration. Devices measuring apparent viscosity give a signal which is a high nonlinear function of consistency and also a function of stock temperature, pH, and fiber characteristics. It appears that a number of instruments might be used in combination with a computer which could, as one of its jobs, correct for the undesired effects to obtain an accurate measure of consistency.

Evaluating the Proposed System

If the system design has been carried far enough, a good estimate of expected benefits and costs can be made. Benefits can be estimated by using the mathematical model of the process to calculate the profit which would have been realized in some period of past operation if the computer control system had been operating. The accuracy of the model can be checked by calculating the expected profit for the nonoptimum conditions actually used in the same period; this figure should agree reasonably well with the profit figured directly from measured raw material and product rates, product quality, utility usage, etc. The difference in profit with and without the computer is as good an estimate of benefits as can be made.

System costs can be figured fairly accurately by adding the costs of the various system components. Payout time, return on investment, or other measures of project attractiveness can then be derived for management consideration.

CONCLUSIONS

While widespread application of digital computers for control of industrial processes has been predicted by many people, installations will not be made merely to be fashionable. It is expected that technical and economic justification will be demanded, with the control computer required to meet the same standards as any other kind of new equipment.

Technical justification for the use of a control computer is found in its ability to deal quickly, accurately, and uniformly with events causing or necessitating a change in process conditions. This capability permits a departure from the present concept of control, summarized very concisely by A. B. Green. Discussing the question of whether color or alum should be added first in coloring paper stock, he wrote (*9*).

> ". . . the practical way of running a mill is to have a fixed rule, one that is nearest right on the average, and one that will not involve a lot of men in the complexities of chemistry."

With a computer to handle "the complexities of chemistry," compromises of current control practices become unnecessary. Instead of simplified rules, charts, and nomographs now supplied to process operators, the computer will use relationships whose complexity is limited by the ingenuity of the system designers. Instead of following fixed patterns or trying to hold constant conditions that are "nearest right on the average," the computer will vary its actions to take advantage of changes in feed characteristics, equipment efficiencies, and ambient conditions.

Granting the possibility of better yields, improved quality, or reduced operating costs, economic justification depends to a large extent on the size of the process. The cost of a computer control system is relatively independent of the throughput of the plant to which it is connected: the same variables must be measured and controlled, and the same calculations performed, for large or small plants. Because of a continuous evolution in control procedures, further improvements are not likely to be spectacular—3 to 5% increases in production rate, for example, have been estimated in a number of studies. For these reasons, the best candidates for computer control are the largest processes.

Nobody should expect that introduction of a computer will bring process operation to a hitherto unattainable state of perfection. Measuring and control devices associated with the computer are not perfect, and the mathematical relationships employed can only reflect current knowledge of the process. Difficulties of instrumentation and mathematical relationships have been met in other industries by cooperative studies carried out by representatives of the computer user and the manufacturer. As would be expected, the first group supplies an intimate knowledge of the particular process under consideration, as well as a general background in the technology of the industry, while the second group furnishes specialized abilities in planning and installing computer control systems. Because of recent advances in the art and science of making pulp and paper, the two groups may now find it possible to solve the problems which are encountered in design and evaluation of computer control systems.

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Analog Simulation of a Complex Level Control System

K. I. MUMMÉ and L. W. ZABEL

The headbox system of a book paper machine could not be operated automatically without either sustained oscillation or overshoot sufficient to cause stock to overflow onto the floor from the Bird screen tubs. The entire system, containing interacting tanks, a nonlinear valve, and nonlinear weirs was simulated on an analog computer. The results of the simulation showed that the control difficulties could not be overcome by any combination of control settings available on the process. They did show that the system could be controlled satisfactorily by either: (1) Use of "Batch reset" action, or (2) changing the measurement point within the system. Cuves show that these solutions are practical. The solution obtained from the simulation was tried on the process, and the paper machine headbox system performed almost exactly as predicted.

Analysis of control systems in the continuous process industries has historically been troublesome for several reasons. One of the principal difficulties, in the case of an existing system, is the fact that experimental analysis is often very expensive in terms of lost machine production. Such an analysis was often a trial-and-error type procedure with the resulting inability to predict the results with confidence. This led to considerable resistance and lack of confidence on the part of the process operators, a situation which was unfortunate but undoubtedly justified.

Classical frequency response analysis methods give extremely accurate results when applied to linear control systems. Unfortunately, linearity is a characteristic often lacking in actual systems. Although frequency response is often useful under linear approximations, extremely nonlinear systems prohibit such approximations and therefore limit the usefulness of the frequency response approach. The system to be studied here was extremely nonlinear.

Analog simulation does not have the theoretical linearity limitations. The computer does, however, have other limitations: (1) the accuracy of the simulation depends upon the accuracy of the mathematical model of the system; (2) the accuracy depends upon the precision of the computer components; and (3) the present simulation required some approximations due to the lack of certain nonlinear computer equipment. The latter limitation is not a theoretical one, but applied to the particular equipment used in the present simulation.

K. I. Mummé, Physicist, and L. W. Zabel, Chief, Instrumentation Laboratory, Kimberly-Clark Corp., Neenah, Wis.

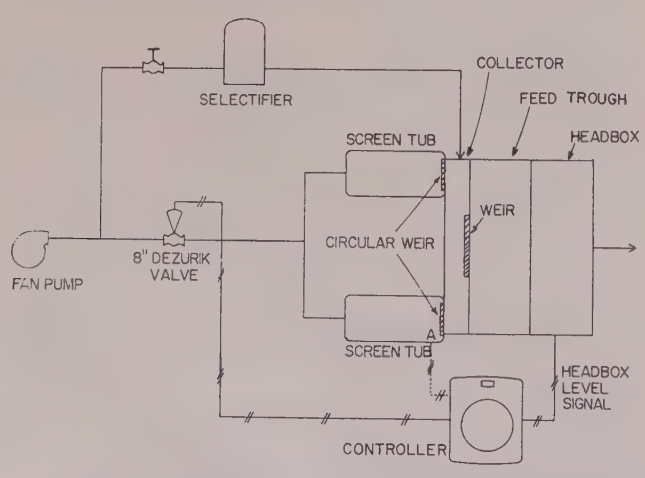

Fig. 1. Block diagram of the headbox system

An analog simulation is based on the fact that a dynamic system can be described by a set of differential equations. This set of equations holds for any dynamic system behaving as described by the equations. Therefore, the system may be mechanical, hydraulic, electronic, etc. Each system is an analog of the other.

The analog computer, operating on the electronic system described by the differential equations, provides a method of solution and description of the dynamics of, in the present case, the mechanical-pneumatic control system. A diagram of the analog computer layout, showing the various simulated physical components, is shown in Fig. 5. Further general discussion of analog computer techniques can be found in the literature (*1*, *2*).

The process to be considered in this paper is the wet-end stock supply system of a paper machine. The system, shown in Fig. 1, extends from the discharge of the fan pump to the discharge of the pressurized headbox. The fact that stock in the Bird screens would overflow onto the floor at every grade or speed change on the paper machine was the basic operating problem.

For economic reasons "trial-and-error" analysis was impractical and because of the obvious nonlinearities caused by weirs, frequency response methods could not be used. Therefore, simulation appeared to be the only practical analysis technique.

Circular weirs are located in the discharge ends of both Bird screen tubs. There is a rectangular weir between the collector and the headbox feed trough. The collector, feed trough, and screen tubs are open topped, while the headbox and selectifier are held under pressure. The control valve, operated by a proportional plus reset controller, is an 8-in. plug valve operating about one-quarter open at the set point. The point of measurement was, orginally, the headbox stock level.

The object of the simulation was, then, to determine the optimum controller settings where optimum operation is defined as the condition where the screen tub level settles to the operating point as rapidly as possible without overflowing.

AN APPROXIMATION FOR THE CIRCULAR WEIR

The flow through a rectangular weir is given by the well-known Francis formula (*3*):

$$F = 3.33\,(L - 0.2H)\,H^{3/2} \text{ cu. ft. per sec.}$$

where

F = flow in cu. ft. per sec.
L = length of crest in ft.
H = head in ft.
$3.33 = 0.415\,(\sqrt{2g})$
g = 32 ft. per sec. per sec.

Figure 2 indicates that the open area of the weir between the weir level and the overflow point can be approximated quite well by a trapezoid. From the geometry:

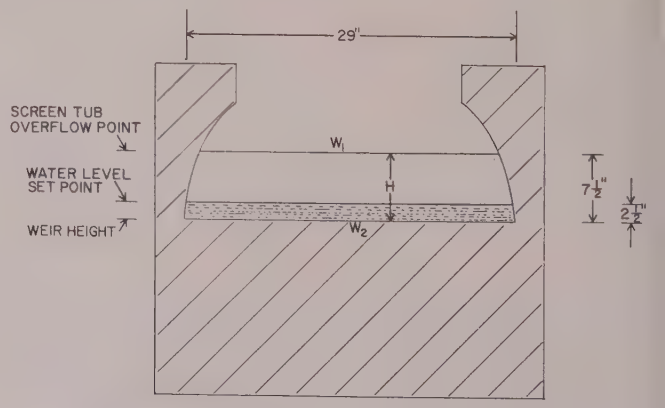

Fig. 2. Cross section of the circular weir

$$L = \frac{Hw_1 - h\Delta w}{H}$$

where

w_2 = minimum width of crest in ft.
H = maximum height in ft.
w_1 = maximum width in ft.
h = height at time t
Δw = w_1 − width at time t
= $w_1 - w_2$ at t.

Assume that $0.2\ H \ll L$. Actually, in this case $L_{max.}$ = 29 in. and H = 7.5 m. $L_{min.}$ = 25 in., so $0.2\ H$ is at least a factor of 10 less than L.

Substituting this value of L in the flow equation:

$$F = 3.33\left[w_1 h^{3/2} - \frac{\Delta w}{H} h^{3/2}\right]$$

Figure 3 is a plot of this equation showing F as a function of h. This function is approximated by the straight line shown on Fig. 3. The approximation is good except near the origin. The straight line approximation permits use of simple feedback on integrator 2, Fig. 5.

The gain and time constant for this integrator can be calculated:

Input − output = accumulation (cu. ft per sec.)

$$e_i - a(h - b) = A\ dh/dt$$

where

e_i = input rate in cu. ft. per sec.
a = slope of Fig. 3
b = h intercept of Fig. 3
h = height above weir
A = area of screen tub

Separating the variables:

$$\frac{dh}{e_i - a(h - b)} = \frac{dt}{40}$$

and integrate to get

$$1/a\ ln\ (ah - e_i - ab) = -\frac{T}{40} + C$$

at

$$T = 0,\ h = 0 \text{ so } C = ln\ (e_i + ab)$$

Combining and eliminating the logarithm:

$$\frac{e_i + ab - ah}{e_i + ab} = e^{-at/40}$$

as

$$h_{max.} = \frac{e_i + ab}{a} \text{ at } t = \infty$$

The time constant is seen to be $40/a$ which in the present case is:

$$T = 40/a = \text{sec.}$$

A plot of height above the weir versus time appears in Fig. 4. Notice that this is also nearly straight between the weir crest and the overflow point. This plot assumes, of course, constant and maximum flow into the screen tubs, which is the open loop case. An open loop control system contains no feedback signal to the control element. Therefore, in the open loop case the control element action is not a direct function of the error signal.

Only one Bird screen is simulated directly. However, the screens, tubs and weirs are identical so the output of amplifier 2 was doubled to simulate the flow from two screens.

Since the circular weir controls only the flow out of the screen tub, the simulation of the tub cannot consider the weir alone. In fact, the simulation must allow for the physical fact that the tubs fill for several seconds before the water level reaches the crest of the weir. Amplifier 1 was used as a switch to perform the above task. A voltage of sign opposite

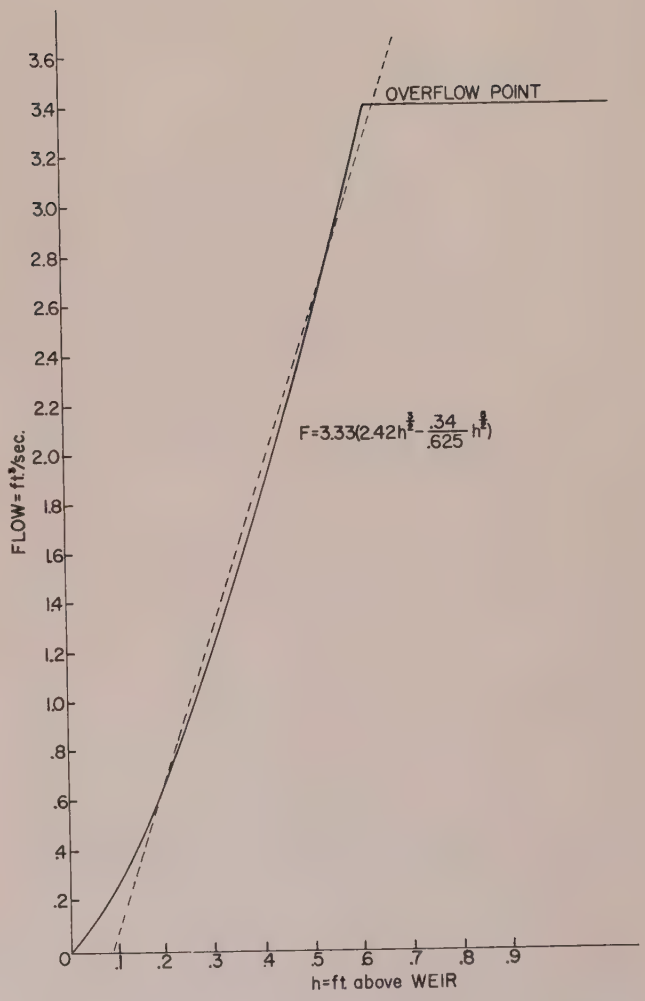

Fig. 3. Flow versus height above circular weir crest

that of the flow signal was put on amplifier 1 and had magnitude equivalent to the height of the weir crest. When the output of amplifier 3 reached this bias point, the relay "flopped" and amplifier 2 began to operate. Amplifier 2 represented the action of the screen when flow over the weir was not zero.

Accumulation in amplifier 3 follows a simple ramp determined by the input flow, which is maximum, and the tub volume since there is no ouptut from the tub until amplifier 2 starts to integrate. Once the relay "flops," the action of amplifier 3 is of no interest. This simulation is allowable since flow across the weir never stops once it has begun in the physical system. The problem is overshoot; there is no undershoot below the weir crest.

THE RECTANGULAR WEIR

The Francis formula for a rectangular weir again was used. Again, it was assumed that $0.2\ H \ll L$, so the operating formula becomes:

$$F = 3.33\ Lh^{3/2} \text{ cu. ft. per sec.}$$

Amplifiers 5, 6, 7, and 9 simulate the collector with amplifiers 7 and 9 generating the $h^{3/2}$ factor. This weir also has no flow until the tank fills to the weir crest level. The bias voltage is applied through potentiometer 6A into amplifier 6. The diode limit at 0 volts prevents negative output when the output of amplifier 5 is less than the bias voltage.

The bias level was set by considering the time required to fill the collector to the crest level with full flow input.

The selectifier, which also flows into the collector, is a simple pressurized tank. The filling of this tank, therefore, follows an electronic RC type curve where the time constant is determined by flow and tank volume.

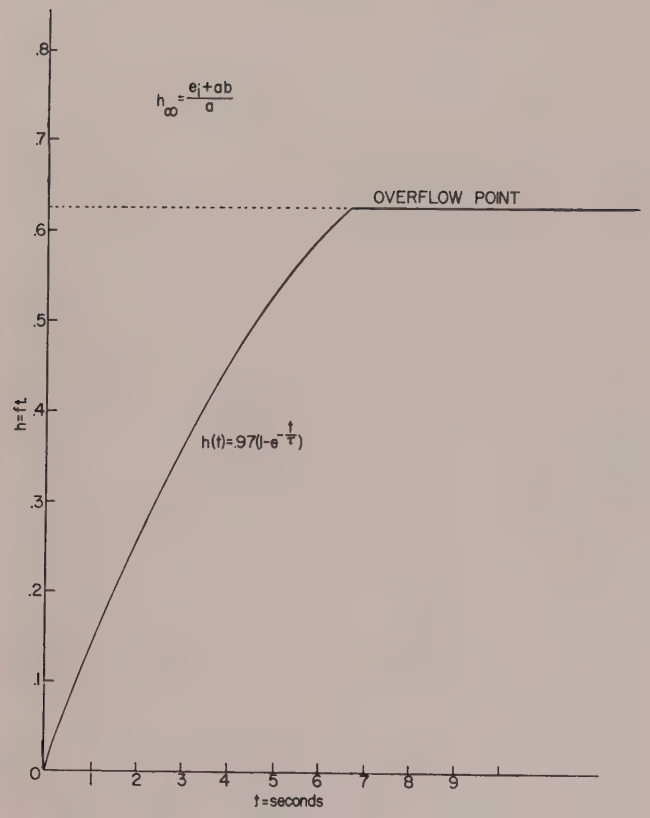

Fig. 4. Stock level above weir crest versus time

THE HEADBOX SYSTEM SIMULATION

From the collector, the stock flows into another open tank called the headbox feed trough. The trough is directly connected to the pressurized headbox, with no weir or other restriction between the two units. Therefore, the trough and headbox act as interacting capacities and require special handling in the simulation.

The time constants were calculated in the usual manner. Although there are amplifier techniques for handling interacting capacities, the simplest method appeared to be the use of ordinary RC circuits. The R_1C_1 network simulates the trough and the R_2C_2 network is the headbox. R_3 was chosen to give essentially zero voltage at the input of amplifier 8, representing the headbox discharge.

The feedback resistor, potentiometer 8B, is for gain control. This value was set to give a voltage out of amplifier 8 equal and opposite to the set point voltage when the outputs of amplifiers 2 and 4 were at the "set-point" values. This automatically accounted for the constants in the flow equation for the rectangular weir.

THE PNEUMATIC CONTROL COMPONENTS

The bias voltage on amplifier 19, provided by potentiometer 9A, is a value equivalent to the desired operating, or "set" point. The output of 19 is the error signal which is fed into amplifier 10. The gain of this amplifier is 100 times the reciprocal of the proportional band. Amplifier 12 is an integrator providing reset action and amplifier 13 provides rate or derivative action. The derivative action has been limited to a gain of 10 since this is the gain limit of most pneumatic derivative controllers. The 0.01-mfd. capacitor was used to reduce random noise. A pneumatic valve with no positioner operates as an RC component. Therefore, amplifier 15 is an integrator with a feedback resistance fixed to provide the proper time constant. This constant was calculated using the measured full stroke time as 99% of the full period. This amplifier simulates the valve motor only. The valve body, or equivalent flow requires special consideration.

The valve in the system is an 8-in. plug valve with a square root flow characteristic. The flow versus per cent travel curve at the physical operating pressure was found in the literature (*4*). A diode function generator was used to generate a function giving the proper square root output curve as a function of a linear input curve. This, of course, simulated the flow as a function of valve motor pressure, i.e., stem position.

To complete the loop, the valve flow output voltage was fed into the screen tub as the controlled variable of the system.

At one point in the investigation an initial condition voltage was applied to the reset amplifier. This simulated a commercially available unit designed to prevent the reset unit from applying full output pressure when a process shutdown creates an error signal. This full pressure output action is commonly referred to as "reset windup." Trials were run both with and without the "antiwindup" feature. This mode of control will be referred to in this paper as "batch reset" action.

VOLTAGE SCALING

Voltage scaling of the system was extremely important. Two scaling bases were used: (1) a scale equivalent to the 3 to 15 p.s.i. pneumatic signal, and (2) a scale equivalent to the various liquid heads.

The pneumatic signal was scaled to give 2 v. per p.s.i. operating from 0 to 24 v. Thus, the simulated air signal was effectively operating between 0 and 12 p.s.i. instead of 3 to 15 p.s.i. However, the important thing, the span, is the same in each case. Diode limiters have been put on the amplifiers simulating reset, derivative, and the valve motor. These limiters prevent the output from exceeding the physical limit of 12 p.s.i. (24 volts) and also the lower limit of 0 p.s.i. (0 volts), since a pneumatic controller cannot change signal polarity. Pneumatic signal scaling begins at the input of amplifier 19 and continues to the input of amplifiers 2 and 17.

Level, flow, or head scaling (they are all related to each other) was based on a value of 100 v. equivalent to the screen tub overflow point. On this basis the circular weir crest level was set at 66 v. The rectangular weir level was set on a time fill basis at an input of 100 − 66 = 34 v. Trough and headbox voltages were not scaled, as they were set by time requirements.

The translations between the scaling systems were accomplished in two ways: The change from the p.s.i. standard to the flow standard was made by making the integration rates of amplifiers 3 and 2 follow the physical fill rates with an input of 24 v. (full flow from the full open valve). The change from the flow standard to the p.s.i. standard was made by

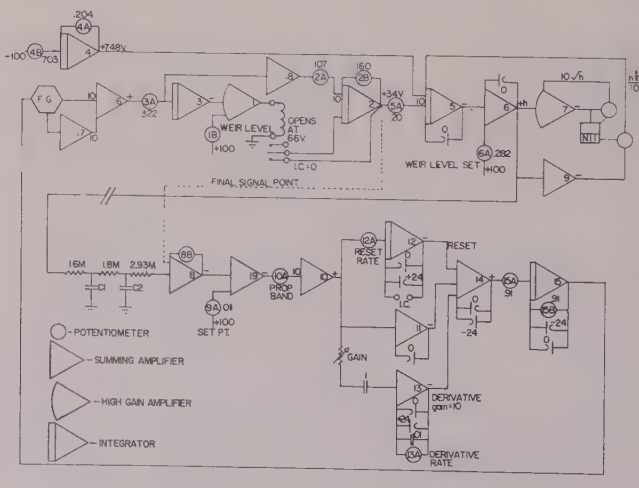

Fig. 5. Computer circuit diagram

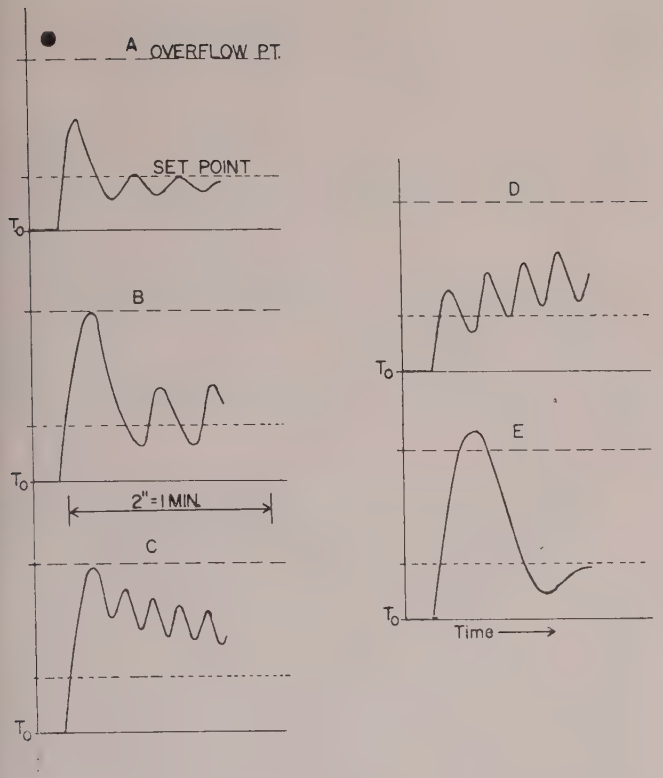

Fig. 6. Response using headbox level measurement and normal control modes

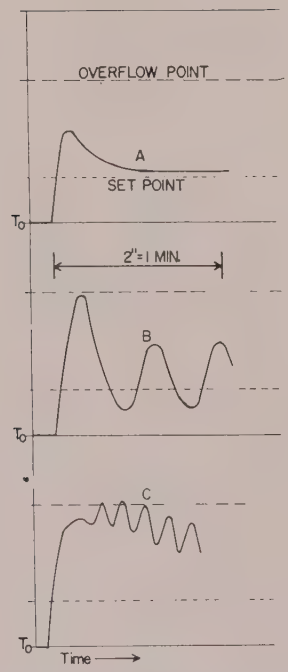

Fig. 7. Response using headbox level measurement and "batch reset" control

setting the set point (potentiometer 9A) in terms of p.s.i. and then setting the gain of amplifier 8 to give zero error signal out of amplifier 19 at a screen level of 77 v. Seventy-seven volts is the value equivalent to the proper operating level in the screen tub.

The entire problem was scaled in terms of real time since no portion of the process or its control system was too fast or too slow for good computer accuracy.

DATA AND DISCUSSION OF DATA

Data were taken under many combinations of proportional band, reset rate, and derivative rate. A fourth mode was also used in place of the standard reset action. This mode was designed to prevent reset "windup" by holding the operating pressure when the process shuts down. Most of the various combinations were tried for each of the measurement points. Because of the large number of curves taken, only the representative or characteristic curves are presented here.

Curves obtained during measurement at the headbox are shown in Fig. 6. These curves were obtained with combinations of the normal control modes: proportional band, reset, and derivative.

Curve A was obtained with 20% proportional control only. The oscillation, though slightly damped, makes this unacceptable. Wider bands reduced oscillation but increased the control offset to an intolerable level. Narrower bands increased oscillation. Therefore, proportional control only could not be used at the headbox measuring point.

Curve B, Fig. 6, was obtained using 10% proportional band and 10 sec. reset time. Reset has increased the overshoot and done little to stop oscillation. All wider proportional band settings caused the screen to overflow when reset of any value was used. Curve C, Fig. 6, was the result of proportional plus derivative plus reset control. The settings were 10% proportional band, 10 sec. reset, and 10 sec. derivative. The large overshoot due to reset again appears, as does the oscillation, but the mean value of the oscillating function drops off toward the set point. This general pattern occurred at all combinations of settings of the three control modes.

Curve D, Fig. 6, uses 50% proportional band plus 20 sec. derivative with no reset. The derivative apparently causes the oscillation, and the wide proportional band permits the large offset. Further trials showed that at narrow bands, the derivative always caused oscillation and at wide bands the offset again exceeded the allowable limits. Curve E, Fig. 6, is typical of the curves that do not oscillate, but the screen tub level has run over; again, an unacceptable situation.

The curves of Fig. 7 were obtained with measurement at the headbox but with a "batch reset" unit on the controller. The "batch reset" unit was set at the equivalent of 6.5 p.s.i. which was the reset value under steady-state conditions. Curve A shows that settings of 20% proportional band and 100 sec. reset gave excellent performance. Curve B used settings of 20% and 50 sec., and shows system instability. Curve C used 10% proportional band, 100 sec. reset, and 10 sec. derivative. Control again became very poor. It is seen that there is a combination of settings which will give good control at the headbox measurement point, but the total data showed the region of useful settings to be very narrow. Therefore, a better solution was desired.

Measurement at the Collector

The curves of Fig. 8 were obtained with the measurement made at the collector. Curve A shows excellent control with little overshoot and rapid damping. The curve was obtained with a 10% proportional band and no reset or derivative. This was the best curve obtained for any combination of practical control settings.

Curve B shows a characteristic common to all of the curves using reset action at the collector measurement point. This characteristic is increased overshoot. This curve was obtained with 10% proportional band and 10 sec. reset time (standard reset unit). Tests not included here indicated that various combinations of proportional band and reset simply give greater overshoot or instability. An example is Curve C, obtained with 10% proportional band and 1 sec. reset. It is obvious from Curve A that no derivative is required.

How the Actual Process Reacted

The actual process did not contain the "batch reset"

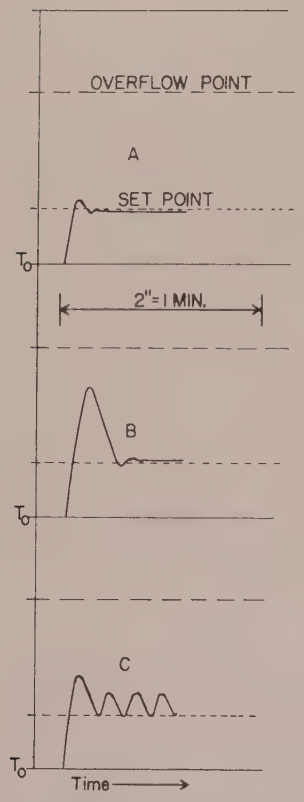

Fig. 8. Response using screen level measurement and normal control modes

feature. As expected, control limits of the system could not be met with measurement made at the headbox. This fact, of course, was the reason for the request for the simulation and the simulation result agreed with the process experience.

As a direct result of the simulation, the process currently operates with the measuring element at the collector. The control settings in current use are 25% proportional band and 18 sec. reset time. These settings give a large "spike," but this is not sufficient to cause the screen tub to overflow. The situation is similar to that shown by Curve B, Fig. 8.

The optimum condition of narrow proportional band and no reset has not been tried on the process. The reasons are caution and tradition. The operators are very hesitant to try to operate with no reset and narrow band since that type of operation is not familiar to them in terms of other headbox control systems. There is also the cautious tendency to "leave well enough alone." The system is satisfactory as it is now operating which makes it hard to convince an operator that much could be gained by further optimizing the settings. From a practical standpoint, the operators are probably quite right in the present case, although this view offers little aesthetic satisfaction.

SUMMARY

Because of computer equipment limitations certain approximations were made in the simulation. In any simulation project the validity of an approximation is an unknown to a greater or lesser degree. In the present case, the approximations were proven to be reasonable by the fact that the results obtained from the simulation controlled the process in the predicted manner when applied to the paper machine itself.

It was found that there was a small region of acceptable control with measurement at the headbox when using a "batch reset" control mode. It was also found that much better controllability was obtainable by making the measurement at the collector. Simple, narrow band proportional control was found to be optimum, with reset adding overshoot and derivative contributing nothing.

These results would have been unobtainable by any other available method of analysis. Therefore, analog computer simulation appears to be a powerful tool in the analysis of process control problems in the paper industry.

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The Application of a Unique Analog Computer to Product Distribution

C. E. McCARTY and W. C. ELMORE

The pulp and paper industry, like other modern industries, has many economic problems which can be expressed as mathematical models consisting primarily of linear simultaneous equations. These problems, which are fundamentally simple, increase in magnitude and complexity as the number of variables and restrictions are expanded. Problems frequently occur in practice which exceed the capacity of large-scale electronic digital computers and even problems of moderate size frequently take hours of computing time due to the iterative process required in their solution. To solve large-scale economic problems a special purpose electronic computer, "AL-PAC," has been developed. AL-PAC solves problems uniquely without requiring iteration. A simple illustrative economic problem is formulated into a mathematical model, and this model is used to depict the theory and operation of this unique computer.

The pulp and paper industry, in common with other modern growth industries, has many economic problems that can be expressed by mathematical models consisting primarily of linear simultaneous equations and/or inequations (*1*). Problems of this type are termed "linear programming" problems, and from a conceptual point of view, are simple in structure but complex in solution when a large number of variables and constraints are present. It is not infrequent to encounter problems that exceed the capacity of computing facilities of a particular company. Many linear programming problems have been formulated, for practical industrial conditions, that exceed the capacity of even the largest computers. Work, however, is currently under way on algorithms that should make it possible to solve extremely large-scale problems using digital computers (*2*).

Linear programming problems are solved basically by two methods: (1) the transportation technique; and (2) the simplex technique.

These, and other related methods for solving linear programming problems require "iterative" procedures (*3*). In the present paper a direct method will be described for solving such problems without the use of iterative steps. Linear programming can be used for economic problems that require optimization when the following conditions are satisfied.

1. The objective to be optimized must be stated in mathematical terms (i.e., cost, profit, etc.) and must be a linear function of other variables in the problem.
2. The restrictions which limit the extent of attainment

C. E McCarty and W. C. Elmore, Scott Paper Co., Chester, Pa.

of the objective must be defined as a linear system of equalities or inequalities.

As with other pulp and paper companies, the Scott Paper Co. is faced with an important economic problem that can be formulated mathematically as a linear programming problem. Basically the company has 10 major producing mills in the United States with more than 60 retail products which must serve approximately 140 sales districts. A major problem exists in the proper allocation of product manufacture to the various mills, together with its distribution to the sales districts. To provide a starting point for an analysis of the problem, a simplification was first made in order to make a hand analysis feasible. Thus 10 producing mills and 17 demand centers with 7 major products were decided upon as an initial problem.

A grueling hand solution was performed to determine how far the then current distribution of company products was from optimum. A comparison of the optimum distribution with the actual distribution showed a possible saving of approximately 5% in shipping charges alone. In working up these results, it became obvious that a computational aid would be required for the analysis, if it were to continue on a regular basis so as to accommodate changing company conditions.

Since nearly all linear programming problems are solved by digital techniques, it appeared logical to investigate the application of a large digital computer to the company's problem. This study showed that a modification of the problem seemed necessary, for no digital program, at that time had been prepared to solve as difficult a "simplex" problem as that presented by the company's problem with its many products. To bypass this obstacle, it was decided to revise the more general simplex problem into the form of a transportation model. This revision lost some of the generality of the original problem but soon proved to be adequate.

Because research people were working on the preliminary phases of the problem, research effort was applied to discover, if possible, a less costly method for solving problems of this type. The probing led to the development of an electronic analog computer that will solve a problem of the transportation type uniquely without iteration.

To provide intelligent discussion of the computer, a complete definition of a typical transportation problem is necessary. Let i refer to the supply points and j refer to the destination points. Then,

S_i = quantity of product available at the ith supply point
D_j = quantity required at the jth destination
t_{ij} = quantity transferred from the ith supply point to the jth destination
c_{ij} = unit cost of this transfer
T = total goods transported
C = total transportation cost

Certain additional facts are known which constitute limitations or restraints. For example, the sum of the quantities transferred along all of the routes from a given supply point must equal all of the quantity available at that supply point assuming that all of the goods are transported. This can be expressed mathematically as follows:

$$S_i = \sum_j t_{ij} \qquad (i = 1 \ldots m)$$

Furthermore the total number of goods transported to a certain destination must equal the quantity of goods required at that destination point if the need is to be satisfied. This can be expressed mathematically as follows:

$$D_j = \sum_i t_{ij} \qquad (j = 1 \ldots n)$$

Finally the total goods transported (T) must be equal to the sum of all the goods available at all the supply points which must be equal to the sum of all the goods required at all the destination points and which, in turn, must be equal to the sum of all the goods transported over all the possible transportation paths. This can be expressed mathematically as follows:

$$T = \sum_i S_i = \sum_j D_j = \sum_{ij} t_{ij}$$

Each of the above equations must hold true subject to the limitation that there is no shipment from destination points back to supply points, mathematically that $t_{ij} \geqq 0$. The objective of the problem is to minimize the total cost of transfer by selecting certain of the transportation routes, i.e., to minimize

$$C = \sum_i \sum_j c_{ij}\, t_{ij} (= \text{minimum})$$

It can be proved, in general, that of the $m \times n$ quantities t_{ij}, only $m + n - 1$ will be nonzero in a solution that minimizes C.

It is possible by a long tedious process of iteration to obtain this solution but, even with the aid of expensive and highly efficient digital computers, it usually requires long periods of computer operation to arrive at the desired solution when many possible routes, or flow paths exist.

Figure 1 illustrates diagrammatically a very simple problem of the transportation type with three supply points ($m = 3$) two destination points ($n = 2$), and the six product flow paths that might be utilized. Each flow path between a supply point and a destination point has a corresponding cost per unit of product flow associated with it (i.e., c_{11}, c_{21}. . . c_{32}). The equations for continuity of product flow and for the conditions of supply equal to demand, are:

$$\begin{aligned} S_1 &= t_{11} + t_{12} \\ S_2 &= t_{21} + t_{22} \\ S_3 &= t_{31} + t_{32} \\ D_1 &= t_{11} + t_{21} + t_{31} \\ D_2 &= t_{12} + t_{22} + t_{32} \end{aligned}$$

The total cost equation for the problem shown in Fig. 1 is:

$$C = c_{11}\, t_{11} + c_{12}\, t_{12} + c_{21}\, t_{21} + c_{22}\, t_{22} + c_{31}\, t_{31} + c_{32}\, t_{32}$$

with the objective of the problem to determine the minimum value of the total cost (C).

The general transportation type of linear programming problem has now been defined in terms of general mathematical notation, and illustrated in algebraic form for a simple, specific problem. Before discussing the electronic

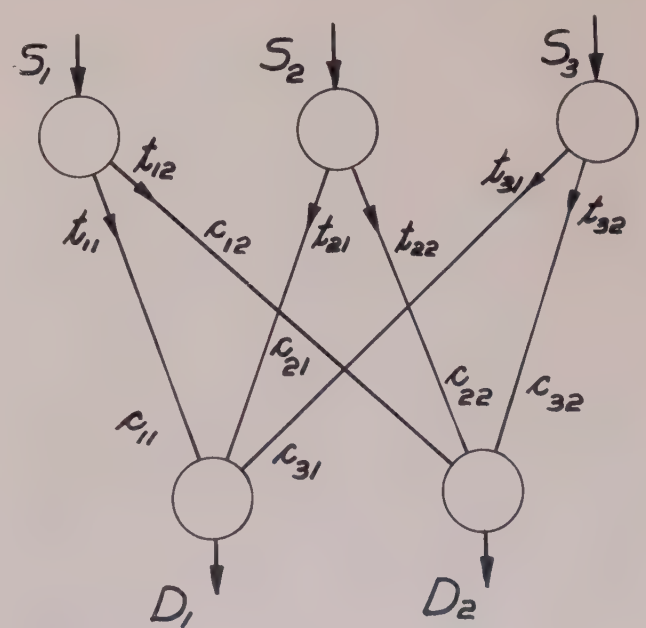


Fig. 1

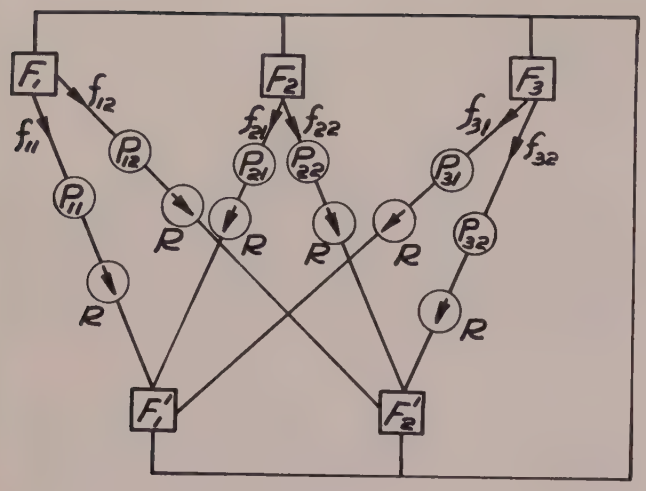


Fig. 2

computer for solving the transportation problem, let us first consider the properties of a hydraulic system with a structure similar to Fig. 1, as shown in Fig. 2. The same restrictions will be placed on the hydraulic network that are placed on the transportation flow diagram. The fluid flows $F_1 \ldots F_2'$ are made proportional to the product flows $S_1 \ldots D_2$, so that the flows f_{ij} are correspondingly proportional to the t_{ij}'s. A constant pressure (P_{ij}), developed by a differential pump is placed in each path to correspond to the cost per unit of product transferred c_{ij}. A simple analysis shows that the hydraulic power delivered to the differential pumps is proportional to the total cost.

The following analogies therefore exist between the transportation network and the hydraulic network, where proportionality constants have been taken to be unity.

$$f_{ij} = t_{ij}$$
$$P_{ij} = c_{ij}$$
$$F_i = S_i$$
$$F_j' = D_j$$

$$C = \text{Total hydraulic power} = \sum_{i,j} f_{ij} P_{ij} = \sum_{i,j} c_{ij} t_{ij} = \text{minimum}$$

The elements in the network (Fig. 2) are the constant flow pumps (F_i and F_j'), the check valves (R), and constant differential pressure pumps (P_{ij}). It is obvious that flow will be established in the paths with lowest opposing pressure and therefore that the flow in the system will divide among the flow paths in such a way as to require the smallest amount of power to sustain the flow. The purpose of the check valves in the system is to allow only one direction of flow, i.e., from the source of flow to the flow destination. A measurement of the flows f_{ij}, therefore, constitute a directly obtained solution of the transportation equations.

The hydraulic analog can be extended to cover situations in which supply is less than, or greater than demand. Let us consider the case in which supply exceeds demand. This means that in the transportation problem the sum of D_1 and D_2 is less than the sum of S_1, S_2, and S_3. To solve this case, three different methods of approach may be used:

1. Supply a dummy variable by including an additional high cost transportation destination.
2. Relax restrictions and then reapply as needed.
3. Insert an element that automatically applies restriction when needed.

The second method will be used for illustrative purposes, although both the second and third methods are used in practice with the electronic computer "AL-PAC" (Analog Linear Programming Algebraic Computer).

First relax the supply restrictions S_1, S_2, and S_3. In the hydraulic analogy this would represent the removal of the flow-restricting devices F_1, F_2, and F_3. Then apply the restricting elements only when the actual flow exceeds the specified limits F_1, F_2, and F_3. Thus the analogous source limits of S_1, S_2, and S_3 are maintained but restricted in magnitude if required to achieve a balance of supply and demand at minimum cost. A similar process can be used when supply is less than demand.

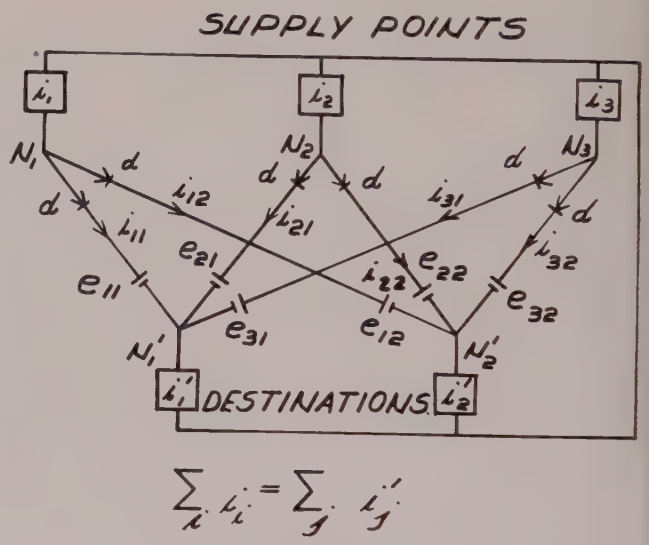
Another direct analog of the transportation problem can be devised consisting of an electrical network containing the elements shown in Fig. 3. The electrical analog, similar to the hydraulic analog, has actual current flow analogous to product flow. The analog constitutes the basis for the practical computer AL-PAC. The network elements of Fig. 3 are:

a. constant current generators (i_1, i_2, i_3, i_1', and i_2') which force definite currents ($i_{11} \ldots i_{32}$) through the network
b. diodes (d) which prevent the backward flow of current
c. constant voltage sources ($e_{11} \ldots e_{32}$) which aid or oppose current flow

The direct analogies between Fig. 1 and 3 are:

$$i_1 = S_1$$
$$i_2 = S_2$$
$$i_3 = S_3$$
$$i_1' = D_1$$
$$i_2' = D_2$$
$$P = C$$

The product of cost per unit of flow and number of units



$$\sum_i i_i = \sum_j i_j'$$

Fig. 3

flowing through a flow path corresponds to the product of voltage and current ($e_{ij} \times i_{ij}$). These products represent cost and power, respectively. Thus, the analog must minimize total power to solve the desired problem.

The direct analogies with general notations are:

$i_i = S_i$ = quantity available at the ith supply point
$i_j' = D_j$ = quantity required at the jth destination point
$i_{ij} = t_{ij}$ = quantity transferred from the ith supply point to the jth destination point
$e_{ij} = c_{ij}$ = unit cost of transfer
$P = C$ = total cost of transporting all goods from supply points to destinations

where

$$C = \sum_{i,j} c_{ij} t_{ij} = \text{minimum}$$

$$P = \sum_{i,j} e_{ij} i_{ij} = \text{minimum}$$

The electrical network equations at the various input nodes (N_1, N_2, and N_3) and the output nodes (N_1' and N_2') shown in Fig. 3 are:

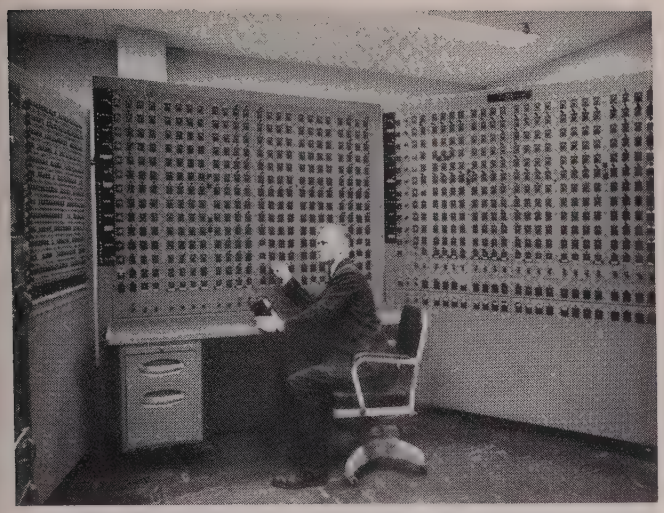


Fig. 4. The analog linear programming algebraic computer, AL-PAC

$$\begin{aligned} i_1 &= i_{11} + i_{12} \\ i_2 &= i_{21} + i_{22} \\ i_3 &= i_{31} + i_{32} \\ i_1' &= i_{11} + i_{21} + i_{31} \\ i_2' &= i_{12} + i_{22} + i_{32} \end{aligned}$$

These equations follow from Kirchoff's first law which states that in an electrical network the sum of the currents flowing to a junction point must equal the sum of the currents leaving the point (*4*). Another basic consideration is the fact that the power delivered to a source of e.m.f. by a current flowing through it is given by

$$P_{ij} = e_{ij}\, i_{ij}$$

The total cost equation for Fig. 3 is therefore identical with the power equation,

$$P = e_{11}\, i_{11} + e_{12}\, i_{12} + e_{21}\, i_{21} + e_{22}\, i_{22} + e_{31}\, i_{31} + e_{32}\, i_{32}$$

The fact that P is minimized by the distribution of currents in the network follows from a general network theorem for the distribution of current in a network which contains sources of e.m.f. and resistances (*5*). In the general case the currents so distribute themselves as to minimize the quantity

$$F = \sum_{i,j} i_{ij}^2\, R_{ij} + 2 \sum_{i,j} i_{ij}\, e_{ij}$$

Two special cases of the function F exist, the second of which is of primary interest to us.

1. The first case is one in which the sum of the power due to the sources of e.m.f.'s in the paths is negligible or absent (because the $e_{ij} = 0$).

$$\sum_{i,j} i_{ij}^2\, R_{ij} >> 2 \sum_{i,j} i_{ij}\, e_{ij}$$

In this case:

$$F = \sum_{i,j} i_{ij}^2\, R_{ij} = \text{minimum}$$

Since the power in each path of the network is the product of the current squared and the resistance (or i^2R), the power delivered to the network is

$$P = \sum_{i,j} i_{ij}^2\, R_{ij}$$

which is here equal to the function F. Hence the internal currents in the network so distribute themselves as to minimize the total power delivered to all the resistances. This result is not useful in a transportation computer because it minimizes a function containing the *squares* of the currents i_{ij}.

2. The second case is one in which the resistance in each path is negligible (it is never entirely absent) but e.m.f.'s exist such that

$$\sum_{i,j} i_{ij}^2\, R_{ij} << 2 \sum_{i,j} i_{ij}\, e_{ij}$$

then F becomes:

$$F = 2 \sum_{i,j} i_{ij}\, e_{ij} = 2 \times \text{power}$$

The sum of the products $i_{ij}\, e_{ij}$ is the power delivered to the sources of e.m.f. in the network. Thus a special case has been derived where

$$P = \text{Power} = \sum_{i,j} i_{ij} e_{ij}$$

is a minimum (the constant 2 is superfluous since twice the minimum of a function is a minimum on the function).

Conditions necessary for the second case to apply have been achieved in the analog computer AL-PAC by careful attention to the magnitudes of the e.m.f.'s, currents and residual path resistances. The practical analog computer now in use is completely transistorized, and handles a 24 × 107 matrix uniquely. This computer is called AL-PAC standing for Analog Linear Programming Algebraic Computer. Figure 4 shows the general appearance of AL-PAC as it is being operated.

The AL-PAC computer can be used as a fixed program computer in which the computer matrix is arranged to accommodate all necessary possibilities, and no additional programming time is required. For a particular problem, the initial conditions are set by means of an ammeter and voltmeter or by setting calibrated dials. A solution is available directly after these conditions are set, and is read out by means of the ammeter. Parameter changes, general operation, and maintenance can be performed by the non-technical operator without, in general, requiring technical assistance.

Let us now see how a problem can be solved on the analog

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computer when it is desired to optimize a production and distribution schedule. The following terms are defined:

A_i = cost of producing a product at i
b_{ij} = cost of transporting the product from i to j

then let

$$c_{ij} \text{ be re-defined as } c_{ij} = A_i + b_{ij}$$

Each cost factor (c_{ij}) includes both the cost of transfer and cost of producing. The voltages in the analog network are set equal to the combined cost of transfer and cost of producing $e_{ij} = c_{ij}$. As before, the problem can be solved as one where supply $\lessgtr$ demand and the techniques for solving cases of unequal supply and demand are the same as described earlier. However, if supply exceeds demand, the computer shows which facilities should be run on a full time basis. Hence the computer provides a solution giving (a) the best distribution pattern, and (b) the best production schedule, with the objective of achieving a lowest total cost.

The computer also provides other useful information from the values of the potentials at the input and output nodal points. This will be illustrated using the simple case shown ing Fig. 3. It is obvious that potential differences must exist between each node and the common current return path. Let us denote these potential differences by

$$V_{N_1},\ V_{N_2},\ V_{N_3},\ V_{N_1}',\ \text{and}\ V_{N_2}'$$

A condition that might exist for a particular problem is

$$V_{N_2} > V_{N_1}$$
$$V_{N_3} > V_{N_1}$$

This means that N_1 is the best producing point, i.e., it is the point where one additional unit of product can be most economically used. For plant expansion, one then thinks of expanding the source of supply at point N_1, or in terms of the original problem, at location of supply S_1 (provided it achieves this low cost by virtue of its situation, and not, for example, by more efficient machines, which, of course, could be added to any of the supply points).

It is often of interest to find what volume of product should be made at the lowest cost producing point under ideal conditions of unlimited plant expansion at this point. An answer is found very simply by removing the current generator which limits the production level of this facility and supplying a "direct connection" to the common current return path in place of the current limiter normally provided. Measuring the current flow through the "direct connection" then provides the optimum producing level at this supply point.

Further useful information is obtained from the node voltages at the destination points. For example, the voltages can be used to help decide the desirability of increasing sales emphasis in the form of advertising, etc., at particular destination points. For example, suppose $V_{N_1}' < V_{N_2}'$, that is, the node potential at demand point D_1 is less than the node potential at D_2. This inequality immediately indicates that the sales emphasis should be placed at the second destination point in view of the higher return per unit sold there.

A problem of still another type can be solved on the analog computer in which the distribution (or production) cost is a function of the amount of product that is being produced by a facility. Assume, for example, that the unit cost

$$c_{11} = A_1 + b_{11} + f(t_{11})$$

The total cost is now a function of production cost (A_1), the distribution cost (b_{11}), plus a cost that is a function of the amount of material being transferred (or produced). To handle this situation on the computer one simply measures the current in path i_{11} (which is analogous to the amount t_{11}) and then in turn corrects the cost voltage e_{11} in accordance with the above equation. This change in cost voltage may or may not change the production and distribution schedule. It is quite feasible with this technique of iteration to consider the effects of several such changes even when these changes involve nonlinear cost functions.

In developing the computer an electrical element has been devised that automatically places an upper restriction on the magnitude of the current flowing through a particular path. Such an element lends itself to the solution of problems where maximum flow through a complex network is desired, as well as proving useful in AL-PAC or problems where supply does not equal demand.

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A New Challenge in Tomorrow's Maintenance

HENRY P. EVANS

MANY of you, as leaders in the paper and pulp industry, are growing more and more interested in the maintenance of your plants. This is as it should be, for day by day your plants are becoming more complex technically, in some cases larger, and certainly in every case—older.

Your interest in maintenance has been kindled to some degree by the current economic situation in your industry. Yearly production of paper and pulp has fallen somewhat below the peak of 31 million tons reached in 1956. Some of your companies have had to absorb wage increases, because the competitive situation did not allow price increases. The result is that profits are down considerably more than is the production rate.

These conditions lead you to ask some searching questions about maintenance. Are your new plants being designed for low-cost maintenance? Are you staffed and tooled to maintain effectively your existing plants at the lowest overall cost?

MAINTENANCE EXPERIENCE

Answering these questions for a complex industrial plant, such as those in your industry, isn't easy. But by drawing on our company's 50 years of experience in engineering, construction, and maintenance, perhaps today we can help you appraise the maintenance effectiveness at your various plants. So first, a word about our background.

For some 40 years, our company has been engineering, designing, and constructing many types of plants for various industries—petroleum, petrochemical, chemical, ore processing, and others. For 50 years, we have been fabricating in our shops a wide range of apparatus—heat exchangers, coolers, condensers, feedwater heaters, reactors, mixers, autoclaves.

With these operations, our interest in maintenance has grown and grown. For example, we are continuously working on more economical ways of designing low-cost maintenance into brand-new plants. We work steadily to maintain the full capability of the production machines in our fabricating shops and the heavy equipment used by our construction division. In 1940, our yearly cost for maintenance ran three times our yearly charge for depreciation of plant. Through continual effort and management attention, we brought our maintenance cost down considerably. For the past 10 years, it has run less than the yearly charge for depreciation.

Several companies, observing the progress we made in maintenance, invited us to study their plants. Thus since 1945, our company has made surveys of some 35 industrial plants and developed maintenance-improvement programs for each of these plants. The surveyed plants range from small ones to some of the largest in the world. They range from fairly new to rather old plants. Most of these plants are in the United States. Some are in Canada, South America, Australia, Indonesia, and Europe. From these surveys and from our work and observations in many other plants, we have further developed our thinking on maintenance. This thinking may help you with the maintenance of your pulp and paper mills.

HENRY P. EVANS, Staff Consultant, C. F. Braun & Co., Alhambra, Calif.

The Usual Condition

In plants experiencing high-maintenance costs, or insufficient maintenance, or sometimes both, we have found certain definite deficiencies. These deficiencies are as follows.

Maintenance policy not well-defined.
Tooling inadequate for the work.
Heavy use of manpower.
Looseness in organization.
Poor records of costs, man-hours, and equipment.
Lack of management interest.

Some plants have all of these deficiencies. But a plant does not need all of them to be plagued with high-maintenance costs or insufficient maintenance.

Maintenance Policy. Let us look at each of these deficiencies separately and in more detail. Many plants do not have a clear-cut management policy regarding maintenance—broad or specific. Few indeed are the plants where the policy is to keep the plant in top condition all the time. More often the policy is simply, keep the plant running at any cost. Often the policy seems to have come out of thin air, rather than from a management study of the combined effects of operating requirements, equipment replacement, essential maintenance, cost of maintenance, economics of contracting certain work of maintenance.

Inadequate Tooling. Most of the plants we have studied are way undertooled maintenance-wise. A few sections, such as the machine shop, may be well tooled. Rare is the plant that is consistently well tooled throughout—in all of the shops, in the field, in the warehouse, garage, offices, and elsewhere. Why this undertooling? Primarily it stems from our tax-laws, from subjective accounting systems that hide costs, and from the fact that it takes less effort to sell management on saving the present dollar as compared to saving the future dollar (*1*).

Use of Manpower. Almost invariably in plants with high-maintenance costs, manpower will be used heavily in place of machine power. Materials handling will be by laborers and crow-bars instead of by fork-lifts or cranes. Manual tools instead of powered hand-tools are the order of the day. Communication is by foot rather than by phone. In many plants, the paperwork and approval to add another man costing $7000 a year is much, much easier than buying a $7000 machine. And the machine may cost only $1000 a year to operate and maintain and may eliminate the need for one or more men. How can this be? It's simple. Accounting can charge a man to expense, without any questions asked. But the capital cost of a machine has to be sold to management, usually with considerably difficulty.

Loose Organization. The plants with high costs usually suffer from a loose organization for maintenance. Sometimes the responsibility for maintenance is loosely divided among the operating groups. Responsibility for supervision is not well defined and supervisors are sometimes spread too thin. Often the maintenance warehouse is made the responsibility of the purchasing department or even the accounting department. Laborers are all pooled in one big yard gang handling both operations and maintenance work.

Poor Records. Another common trouble in these plants is the poor records kept on maintenance. Many times, no one will be able to provide a sound figure for the total cost of maintenance. Even the figure for man-hours of labor spent on maintenance will be highly variable—depending on who is

talking—the accountant, the plant manager, or the maintenance superintendent. Often no records will be available as to what is or has been spent to maintain major items of operating equipment.

Lack of Management Interest. Maintenance in these plants is treated as an unwanted stepchild. It gets little management attention, not anywhere near its fair share of leadership and other talents, almost no facilities, almost no consideration of any kind.

RESULTS OF MAINTENANCE APPROACH

The weaknesses described above—and many of today's plants still show them—combine to affect maintenance adversely. The results are high maintenance costs, limiting of production, lowered morale of employees, negative effect on sound maintenance practices.

High Costs. In plants with these weaknesses, the effect on maintenance costs has been staggering. Some of these plants kept one half of all their hourly employees busily at work on maintenance, yet their plants were not maintained to their satisfaction. Expenditures for maintenance materials equaled or exceeded the expenditure for maintenance labor. An oil refinery with a replacement cost of only 28 million 1959 dollars typically had a base-crew of 220 hourly men working on maintenance alone. When management attempted to solve the problem by putting a ceiling on the size of the huge maintenance force, the refinery had to resort to using outside shops and contractors to handle a large part of its maintenance workload.

Limited Production. The effect of these maintenance weaknesses on a plant's production is not easy to measure. But, it is apparent in several ways. Emergency shutdowns occur more often and last longer. Charge stocks to process units have to be wasted, lost, or reblended. Products fail to meet quality standards more often. Even the scheduled shutdowns require more work and last longer. Some idea of the magnitude of this effect can be gained by looking at the onstream service-factors of a continuous-type plant, such as an oil refinery. Here a lack of maintenance capability can cause a refinery's total down time to increase by 5 to 10 days a year. For a refinery running 100,000 barrels a day, this increase in down time may reduce net income, after federal taxes, by as much as $500,000 a year.

Other Effects. When maintenance capability is below average, other ills often result. The efficiency, the interest, and the morale of the individual maintenance man goes below par. It becomes difficult to effectively apply proven practices, such as planning and scheduling of major work, materials control, cost control, preventive maintenance. These effects, although intangible, cost real dollars.

New Plants. One may say, sure these weaknesses exist, but they are not the rule in modern, well-designed plants (*2*). Last May, the editors of *Factory* selected the ten best new plants in 1958 after a study of 700 plants built that year (*3*). After describing each of the winning plants, *Factory* editors have this to say about maintenance.

"Every one of the winners is designed for low-cost maintenance. The evidence sticks out all over. But action seems to peter out right there. From a study of maintenance management practices set up for these plants *Factory* editors get this impression. In most of the ten winning plants, maintenance management planning for economic operations lags far behind building and equipment design."

PRINCIPLES OF ECONOMIC MAINTENANCE

From our surveys, we find that plants are quite different maintenance-wise, even those with almost identical processes and making the same products. Thus any program developed for improved maintenance must be tailored to fit the particular plant.

Four Principles. We have analyzed each one of the improvement programs developed by us during the past 15 years. They cover plants of many types and many sizes. Nevertheless, we find that all of these tailor-made programs stem from the same basic principles. These principles, the key to economic maintenance, are four in number.

1. Establish a clear-cut policy on maintenance.
2. Tool and train the maintenance man.
3. Combine and centralize the facilities.
4. Provide a sound organization and good methods.

Policy on Maintenance. The policy on maintenance should be as clear-cut and as definite as management can possibly make it. The policy should govern many of the day-to-day actions and decisions on maintenance. It should cover all of the following key points, at least.

1. Service factors to be attained over a specified period.
2. Useful life expected from major production units.
3. Basis for evaluating replacement as compared with continual repair of equipment.
4. Extent of housekeeping effort.
5. Types of maintenance work to be handled by contracting.
6. Amount and type of construction work to be handled by maintenance department.

Tool the Man. The principle, tooling the maintenance man, is perhaps the most important of all. Tooling the man, as used here, has a broad definition. It includes such things as offices, furniture, shop machines, industrial buildings, light, heat, roads, mechanical handling-equipment, trucks. All of these tools should be suitable for the work of maintenance. The first step toward effective, economic maintenance is to properly tool each maintenance man, be he laborer, craftsman, office worker, helper, or superintendent (*4*).

Combine and Centralize. The facilities for maintenance should be combined and centralized. Combining means locating the major facilities, especially the shops and the warehouse, in one building. This combining reduces the investment in buildings, reduces the cost of handling, of manpower, and of tooling. It promotes cooperation among the crafts, fosters coordination of activities, and provides flexibility for growth. Centralizing means bringing together in one area all of the maintenance facilities that properly belong together—shops, headquarters for field crafts, stores, cleaning facilities, garage, offices. This centralizing reduces and simplifies handling, improves supervision, avoids duplication, and permits an effective flow-pattern for the work.

Organization and Methods. The organizational pattern for the maintenance department should be clearcut, should define and fix the responsibility for the various activities, and should generally be of the line type. It should put under one leader all of the activities that are concerned with the work of maintenance or contribute to it. The maintenance methods, both mechanical and paper, should be truly up-to-date. Particular attention should be paid to the planning and the scheduling of work, the amount of preventive maintenance, repair and salvage, work-order system.

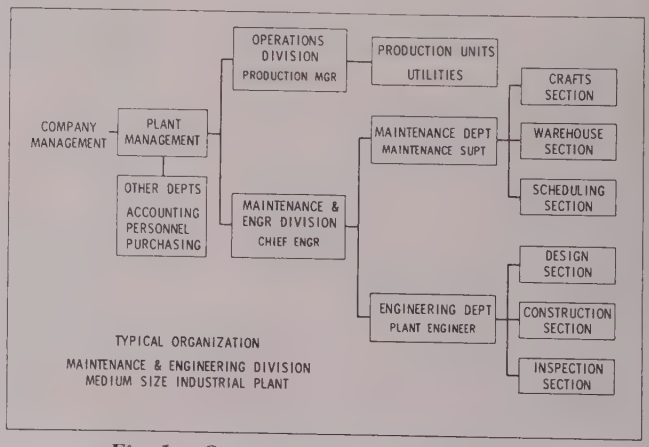

Fig. 1. Organization for maintenance

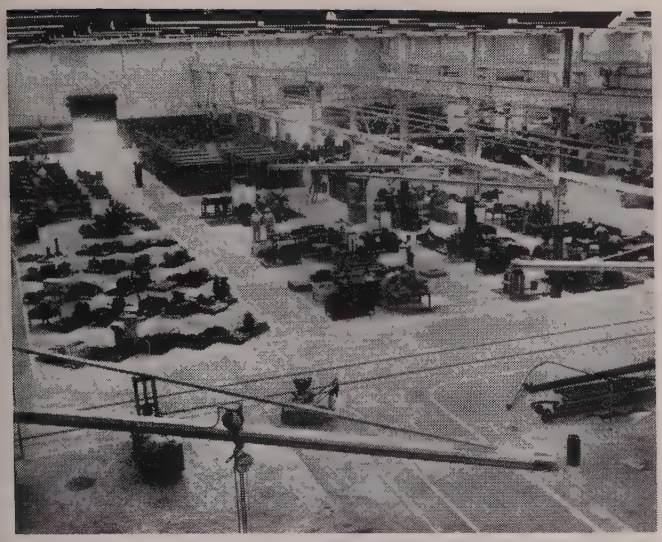

Fig. 2. Maintenance Shops

Application of Principles

These principles, like most principles, are easy to state. On the other hand, their application to a specific plant, brand new or existing, is sometimes difficult to work out. Perhaps a description of how these principles can be applied to a medium-size industrial plant will lead to a clearer understanding of how they are applied and the benefits that can result.

Management Policy. For this discussion, assume the management clearly wants effective, efficient maintenance at low cost and so states this as a broad policy. Knowing what is wanted, in itself, is a big step forward. Assume, too, that management goes further and sets specific guides for maintenance. These guides set forth the following objectives. Production units are to have high service-factors, say roughly 95%. Replacement of equipment is to be favored over repetitive major repairs.

Housekeeping is to be good or excellent, not minimal. Contract maintenance is to be limited to specialized or infrequent work which outsiders can do more economically. New construction by the maintenance department is to be limited to the small, straightforward type of job and is not to constitute a major effort. Now let us apply our second principle —tooling.

Shops. The maintenance shops are an especially effective place to apply the principle of tooling the maintenance man (*5, 6*). All of the craft shops—such as machine, weld, pipe, boiler, electric, instrument, carpenter, valve, paint, sheet-metal—should preferably be brought together in one building. For low-cost handling, this building should have bridgecranes, jibcranes, fork-lifts, wide aisles. This building should provide ample working space, vertical as well as horizontal. The width of a bay should be not less than 60 ft. and often wider. Clear space from underside of bridgecrane to the floor should be ample for high lifts and certainly not less than 16 ft. Illumination should approach the values recently recommended by the Illuminating Engineering Society. For many geographical locations, the shops should be air-conditioned. The machine tools in the shops should be of modern design and flexible, not hand-me-downs or single purpose, and should probably include the following tools.

Milling machine	Hydraulic press
Vertical boring mill	Balancing machine
Shaper	Pipe machines
Radial drill	Pipe rotators
Drill presses	Welding machines
Lathes	Positioners
Metal bandsaw	Cleaning facilities
Power hacksaw	Paint spray booth

Shop Work. The sizing, planning, and layout of the shops should be based on doing most of the repair work in the shops rather than at the production units. In the shops, the proper tools, effective handling, and skilled craftsmen are readily available. At the production units, maintenance men must resort to makeshift methods, jury rigging, and handtools.

Mobile Equipment. An industrial plant needs mobile equipment to haul equipment from the production units into the shops for repair. And the plant needs mobile equipment to haul men and their tools to all parts of the plant, and to lift and move many types of process equipment and materials. The mobile equipment fleet should usually include several types of trucks for hauling, several fork-lifts for handling, a small but highly maneuverable crane, and a truck crane with a long boom. The mobile equipment has to be the right type, sufficient in quality, and well maintained. Otherwise, a lot of shopwork will not be brought to the shops.

Garage. Maintaining this mobile equipment will usually call for a garage inside the plant. Too often this garage is little more than an open shed. Tooling a plant garage calls for facilities for washing and lubrication, for automotive and fork-lift repair, for tire repair. For effectiveness and economy, these operations will need such things as a hydraulic lift, pressure-lube equipment, battery chargers, motor analyzer, and so on.

Roads. For mobile equipment to do its work, the equipment must be able to move quickly to and into the production units. This calls for something more than single-lane gravel roads. The plant roads should be straight, two lanes wide, paved, well drained, and clear of pipe supports, valves, hydrants, and power poles. Major units of the outdoor type should have roads along all four sides. Maintenance of a production unit may require the parking of vehicles alongside the unit and the working of equipment from a road. Then it is sound economy to provide a wide paved shoulder alongside that road.

Accessways. Access from a road into a unit, whether the unit is outdoors or indoors, is as important as the plant's road-

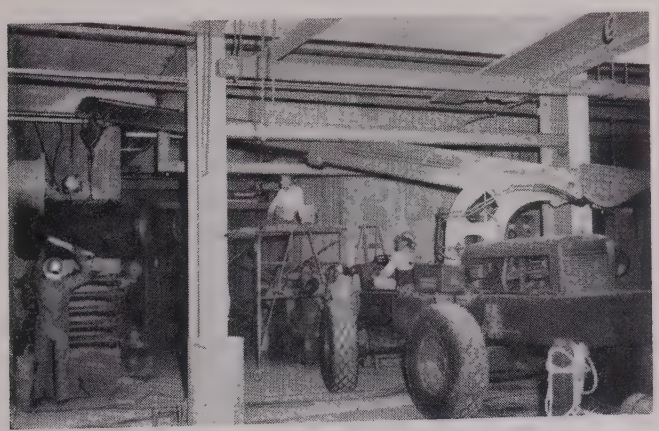

Fig. 3. Small mobile crane

Fig. 4. Plant garage

Fig. 5. Plant road

system. Accessways should run through a unit, rather than dead-end. Accessways should be straight, paved, fairly wide, clear of obstructions, and provide the necessary vertical clearance for small cranes. Good roads, proper accessways, and the right mobile equipment, all combine to make it practicable to take shopwork out of the unit and into the shops where such work really belongs.

Warehouse. One phase of maintenance often almost completely overlooked is the warehouse. Yet the warehouse in a medium-size plant is a big business. Such a warehouse will issue several million dollars of maintenance materials each year, store 10,000 to 20,000 different items, and be responsible for quickly producing vital spare parts and spare equipment. For effective operation, the maintenance warehouse not only needs but deserves more than some leftover buildings from plant-construction days.

The warehouse should be set up to deliver maintenance materials to the shops and to the field when needed, where needed, and with the least handling. This calls for the warehouse to be in the same building as the shops. Materials then can be stored in the same bay as the shop that uses these materials. Fork-lifts and utility trucks can use the building aisles to deliver most items quickly. Heavy items can be handled by the same bridgecrane that serves the shops. And materials stored in the shops and elsewhere can be limited to a few days' supply of the small items used daily.

The warehouse should be laid out and tooled so that modern methods can be used for handling and for storage (*7*). Pallets, pallet boxes, and pallet racks should be used wherever practicable. Reel racks, bar racks, and other specialized racks should be used for odd-shaped items. When so tooled, warehouse labor costs go down and cubic feet of space are used

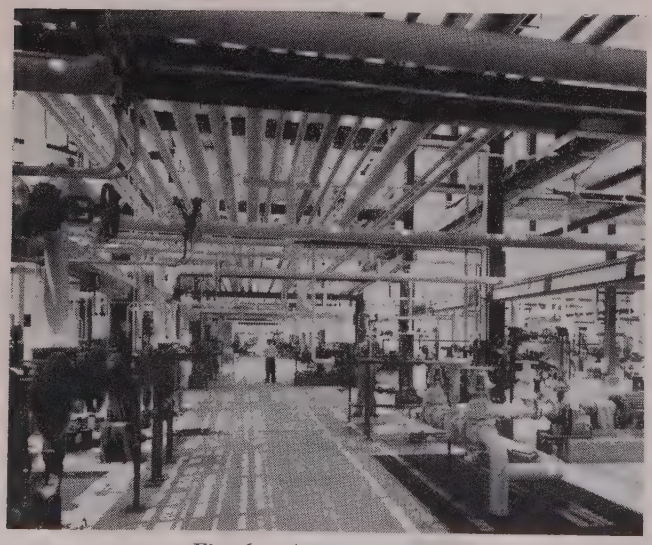

Fig. 6. Access into unit

Fig. 7. Modern warehouse

rather than just square feet of floor or sq. ft. of outside yard.

Organization. The organizational pattern for a maintenance department cannot be the same for all plants, since the pattern has to be tailored to fit special situations caused by personnel, location, over-all company organization, and other factors. However, the pattern can be made clear, and can fix and define responsibilities. The troublesome areas usually are the warehouse, transportation, minor new construction, contract maintenance, and maintenance engineering. The maintenance department is usually involved in these areas more than any other single department. Thus the maintenance department should generally be made responsible for the warehouse, garage, mobile equipment, minor new construction, and contract maintenance. On the other hand, the maintenance department is only a team-member of plant organization and should not be permitted to engage in empire-building.

Methods. Many good articles have been published on the various paper methods for maintenance. They emphasize the need and describe methods for planning, scheduling, standards for repetitive work, preventive maintenance, equipment records, keeping of costs, work-order systems, spare-parts control (*8*). In large industrial plants, these systems are a necessity. They keep costs from getting way out of hand. These systems, however, should not be looked upon as a cure-all for every plant. The improvement possible by using these systems, measured either in increased effectiveness or in lower cost of maintenance, depends largely on the tools provided for actually doing the physical work of maintenance.

Offices. A maintenance department needs office space for certain people in shops, warehouse, planning, supervision, and so on. And the department needs space for conferences

Fig. 8. Methods of storage

and training. Again the principle of tooling comes to the fore. Too often, maintenance offices are crowded and makeshift, as well as poor and dirty in appearance. Offices should be well furnished, convenient, comfortable, and neat appearing. Tooling office space pays through increased work output, improved morale, and the respect gained from others. Office tooling really pays—surely tenfold, maybe twentyfold.

Built-In Handling. Mobile equipment for handling heavy or bulky objects has been improved considerably in recent years. Many new types of equipment have been developed. Thus the trend in plant design is to cut down on built-in handling facilities and to make more and more use of mobile handling-equipment. This is especially true for the outdoor type of plant. However, built-in handling may yet be the solution in certain situations, either by necessity or for economy. Certainly, consideration should be given to built-ins for such things as large compressors in line, and major maintenance items located 50 ft. or more above ground.

Contract Maintenance. In the last 5 years, several plants have gone to contract maintenance. And there seems to be a continual interest in this arrangement. There are three basic types of contract maintenance.

1. Contractor maintenance of entire plant.
2. Contractor maintenance supplementing the owner's small base-crew.
3. Contracting of special, infrequent, or peak-load maintenance.

The decision to use a contractor to maintain the entire plant or to supplement the owner's small base-crew, depends on factors too numerous and too involved to discuss fully here (*9*). However, the use of contractors or outside shops for special, infrequent, or peak-load maintenance, is usually a matter of available skills and costs.

Many plants have certain maintenance that contractors can do better and for less money. Here are the types of maintenance that a plant should consider contracting rather than using plant personnel.

1. Work calling for special equipment, special knowhow, or for unusual craft-skill. Examples of such work are chemical cleaning of tubular equipment, rewinding of electric motors, servicing of water wells, heavy machining.
2. Work occurring so infrequently that plant personnel cannot handle it effectively and efficiently. Examples of such work are major replacement of refractory brick, special linings, major plumbing repairs.
3. Work best handled by concentrating on it at a selected time. One example of this is the repainting of large production units.

INVESTMENT OF CAPITAL

Tooling up for low-cost maintenance calls for the investment of capital dollars. But it's not nearly so costly as some believe. Some plants will have already invested in such things as good plant roads, proper mobile equipment, and built-in handling facilities. Based on our surveys, most of the capital invested in tooling for maintenance will go toward building and equipping the shops, the warehouse, and the garage.

There is no rule-of-thumb available for estimating the investment required for proper maintenance facilities for a specific plant. Our studies indicate that this investment may range anywhere from 2 to 5% of the replacement cost of a plant depending on size, type, age, and other characteristics of a plant.

The primary objective of proper maintenance facilities is to cut the yearly expenditure for direct labor. Since the hourly pay of the maintenance worker is increasing at a more rapid rate than replacement cost, it appears most economic to provide the proper maintenance facilities just as early as possible.

The Payout

Assume an industrial plant has been provided with well-designed production units but with very limited facilities for their maintenance. As the production units grow older and as new units are added, the high maintenance costs to higher and higher. What can be done to bring these costs down, especially when hourly wages are constantly climbing?

Usually the organization and systems can be improved. But the ultimate effectiveness of such improvements is essentially limited by the tools provided for the maintenance men. To really bring costs into line, the proper tools must be provided. And again we are speaking of tools in the broad sense—buildings, shop machines, warehouse equipment, offices, and so on.

To get such tools, a plant must spend some capital dollars. But many segments of a growing company are bidding for these same capital dollars. Some groups want to add production facilities. Others press for replacement of obsolete production units. Some want new equipment to comply with new requirements established for pollution and for safety. How can management justify spending capital money on maintenance?

Here is the justification. These tools earn their way by decreasing the manhours spent on maintenance, by cutting down the money spent for maintenance materials, by decreasing the down time of key production units, by cutting down the emergency work and the overtime.

When all these factors are evaluated, the investment in maintenance facilities will usually have a payout equal to or better than most improvements in plant. The payout time will sometimes be as rapid as one year, usually about 2 years, and seldom more than 3 years. The other attractive thing about these maintenance facilities is their long, useful life.

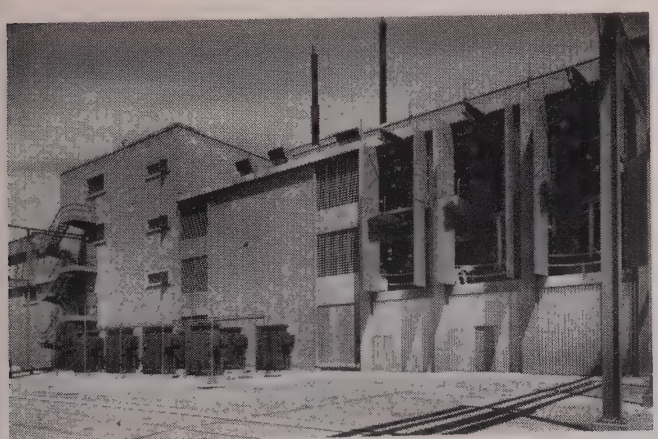

Fig. 9. Built-in facility for handling

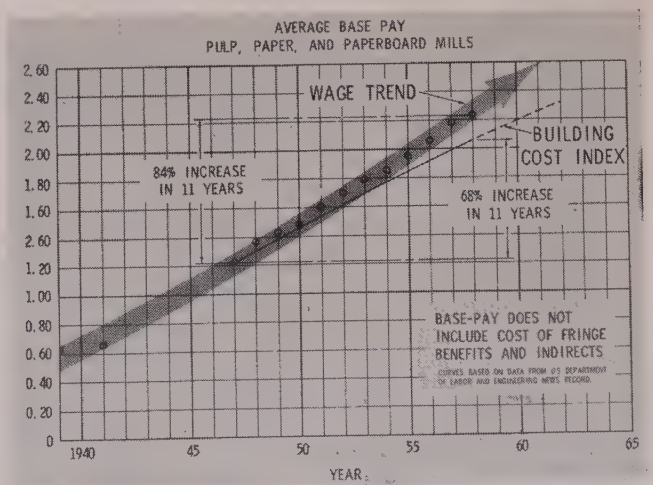

Fig. 10. Trend of wage rate

When properly engineered, most of the facilities will serve adequately for 15 years or more.

SUMMARY

Day by day, your plants are becoming more complex—not simpler. Advancements in recent years have introduced larger production units, more types of specialized equipment, more instrumentation, automatic controls, new alloys, and a host of other improvements.

Generally speaking, such improved plants require fewer and fewer operators. On the other hand, such plants call for more maintenance skills and sometimes more actual maintenance work than did yesterday's plants.

Therein lies the new challenge in tomorrow's maintenance—how to do more types of maintenance more skillfully without having maintenance costs increase and offset operating economies. This challenge cannot be met by the simple expedient of adding men or by deferring maintenance. Rather it has to be met by establishing a policy for maintenance, by organizing for the work, and by providing maintenance people with the tools they need. Certainly tomorrow's maintenance deserves the top attention of management today.

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Recent Improvements in Pulpwood Grinders for Insulating Fiberboard Manufacture

WILLIAM F. FIELDS

There are some people in the paper industry who feel sincerely that engineers should stop their continual changing and re-designing of machinery and equipment, put their heads together, and decide the one best way to build a given piece of equipment so that the industry would have a standard refiner, a standard winder, a standard stock pump, and, yes, even a standard wood grinder. In this way, it is proposed that through the use of standard designs many engineering hours would be saved with a consequent saving in the cost of production facilities to the industry. D. W. Ambridge, president of Abitibi Power and Paper, Ltd., expressed this view in his speech entitled, "The Urgent Needs of the Industry" presented during the 8th Engineering Conference at Montreal in 1953. (*1*).

When the steady progress that has been made in machinery and equipment design, production rates, and quality standards since the days of that famous Chinese inventor of paper, Ts'ai Lun and his 105 A.D. model handsheet mold, is considered, it is apparent that it would have been unfortunate for the industry and for the general economy if engineering designs had been frozen at some time in the past. For this same reason, it is unthinkable that this could happen in the future for since the days of Mr. Lun the increasing cost spiral for capital additions coupled with demands for better quality products have and always will make it profitable for the industry to look continuously at the design of production equipment with an eye to making improvements, to increase capacity per unit of investment, reduce operating costs, and improve product quality. In essence this is the job of the engineer.

The case in point is the wood grinding operation at the Macon, Ga., plant of the Armstrong Cork Co.

William F. Fields, Project Engineer, Central Engineering Dept., Armstrong Cork Co., Lancaster, Pa.

SELECTION OF THE GREAT NORTHERN GRINDER

The development work by the Armstrong Cork Co. leading to the selection of loblolly pine mechanical pulp for the manufacture of insulating structural fiberboard was carried out at the Herty Laboratory at Savannah, Ga., shortly after World War II. This work led to Armstrong's unique method of grinding wherein the wood is ground with the grain oriented parallel to the direction of movement of the grinding surface rather than at right angles. The reasons and theory behind this method are beyond the scope of this paper but are detailed in the patent disclosure on this process. (*2*) In general, the resulting stock, which is produced with an energy consumption of 30 hp. per daily ton, is quite coarse and has a Canadian freeness in the range 300 to 500 cc. Of the total fibers 70% are retained on a 65-mesh screen, and 7 to 20% of total fibers are retained on a 10-mesh screen.

After careful study, the 54 × 34 in. Great Northern grinder was judged as being in all respects the most suitable grinder for this method of pulping and was selected for Armstrong's Macon plant during the early engineering planning stages in 1946. The only modifications made to the standard grinder design were minor changes to the pockets to facilitate parallel grinding.

DESCRIPTION AND HISTORY OF THE GREAT NORTHERN GRINDER

A sketch of the grinder is shown in Fig. 1. The grinder is of the two-pocket type with the pockets inclined 20° above the horizontal axis of the shaft. The pocket size is 27 in. deep by 33 in. wide. Each pocket is equipped with a brass-lined hydraulic cylinder 20 in. in diameter with a 24 in. stroke, which actuates the pressure foot used to hold the wood against the stone. A magazine or wood box is mounted directly above each pocket and holds one charge of wood for the pocket. A sliding steel plate operated by a second hydraulic cylinder forms the top of the pocket and the bottom of the wood box. When the plate is withdrawn, the measured charge of wood drops directly into the pocket. The maximum allowable operating pressure in the cylinder is 180 p.s.i., which would result in a theoretical 70 p.s.i. pressure against the stone if the pocket were filled solidly with wood. To compensate for irregularities and voids in the wood, as well as time periods when only one pocket is grinding, the grinder is usually provided with a governor which increases or decreases the hydraulic pressure to hold the torque and, therefore, the power input to the grinder constant. The shaft diameter

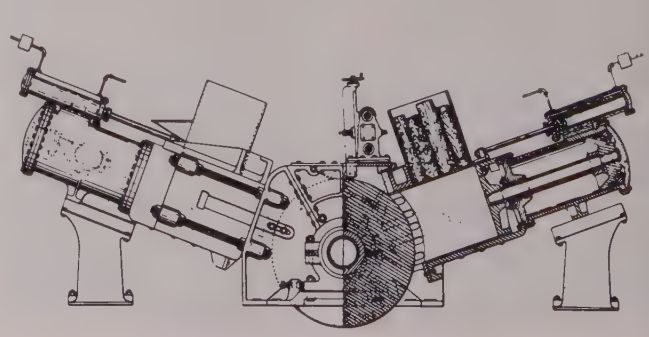
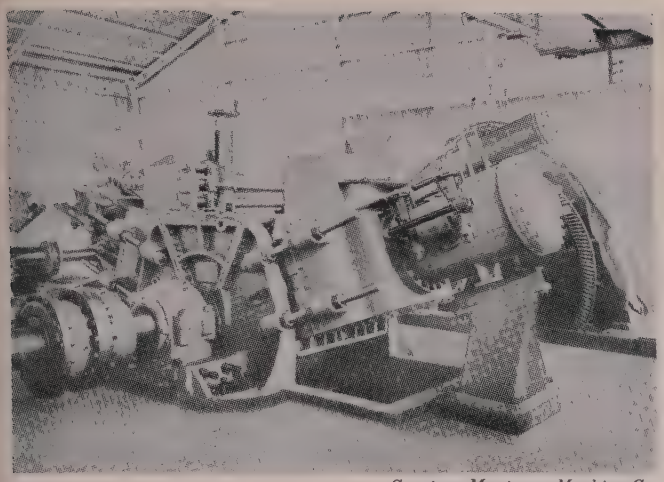


Fig. 1. Section of Great Northern grinder



Courtesy Montague Machine Co.

Fig. 2. Typical Installation Great Northern grinder

is 13 in. at the stone and $10^{3}/_{4}$ in. at the bearings. This is a very simple and rugged machine, weighing over 23 tons without the stone (Fig. 2).

The grinder was originally developed at the East Millinocket, Me., mill of the Great Northern Paper Co. starting in 1922 with the first major installation of 12 grinders being made during the period 1929–31 (*3*).

Initial Grinder Installation

When Armstrong's Macon, Ga., plant was started up in 1947, the pulping operation consisted of four of these grinders arranged in tandem, each pair being driven by a 3000 hp., 80% power factor, 240 r.p.m., synchronous motor. Governors were provided for hydraulic control, which varied the cylinder hydraulic pressure to keep the load on the motors at a constant level. With both pockets grinding, the average pressure of the stone against the wood was approximately 45 p.s.i.

These grinders operated very satisfactorily for 8 years when it became necessary for Armstrong to make a 150% expansion to its Macon operation.

Preliminary Expansion Studies

The decision was made to add more capacity for the mechanical pulping of loblolly pine with Great Northern grinders rather than to consider other wood species, pulping methods, or types of grinders for the expansion. Preliminary plans called for three additional tandem grinder lines to duplicate the two lines originally installed to achieve the 150% capacity increase. However, before finalizing the plans, a study was made of the original installation to determine if design improvements could be made to improve the efficiency of the grinders and/or improve pulp uniformity.

ENGINEERING ANALYSIS AND DEVELOPMENT OF GRINDER IMPROVEMENTS

Insofar as design was concerned, the basic side frames, shafts, and bearings of the machine, simple and rugged as they are, could hardly be improved upon. Analysis was concentrated on the wood-stone interface in the grinder. The first and obvious variable here was the surface speed of the stone. The first objective in the direction of increasing capacity was to determine if the surface speed could be increased, and if so, to determine the maximum allowable speed.

An investigation of existing grinder installations was made, and it was found that on 54 in. stones most installations were operating at synchronous speeds of 225 to 240 and 257 r.p.m. or at a maximum surface speed of 3620 f.p.m. The fastest stone found in production was in operation in Norway and was running at 5120 f.p.m. While no installations of 54 in. stones were found operating faster than 3620 f.p.m. on larger stones, speeds of 4000 to 4500 f.p.m. were found to be quite common in this country and in Canada. Concern over the effect on the quality of the pulp and not mechanical limitations finally led to the selection of 300 r.p.m. or 4250 f.p.m. for the new grinders.

Observations over the 8 years of operation of the original grinder installation indicated that there were considerable production losses due to the time required to retract the grinder pressure foot after a pocket was ground out and in advancing the new charge of wood to the stone face before actual grinding commenced. With the standard hydraulic systems provided for these grinders, the low pressures in the water hydraulic system coupled with the large forces required during the grinding cycle required that large volumes of water be inletted and outletted from the cylinder during the grinding cycle. To get fast action in a system of this type, extremely large valves and piping must be provided. However, there is a limit to the attainable speed for a given system, for as the acceleration and deceleration of large masses of fluid are increased, problems with shock or "water hammer" become severe. The second objective in the direction of increasing capacity was to increase the speed of the pressure foot during nonproductive portions of the grinder cycle (retraction and advancing wood to the stone surface).

The method of controlling the pressure foot by controlling the pressure in the hydraulic cylinder, which in turn is regulated by motor load, was re-examined. If wood were a homogeneous material, if it were possible to fill the pockets solidly with no voids and operate with both pockets grinding at all times, this type of control would produce a uniform pulp. In fact, if the above conditions were found in practice, no control would be needed. Because of voids, knots, wood density variations, pulpwood arching in pockets, and time periods when all pockets are not grinding, the wood is forced into the stone with variable unit pressures and at varying rates. As a result, the characteristics of the pulp vary widely with respect to fiber size and structure. The pulp produced under low pressure conditions is different from the pulp produced under high pressure conditions because of the consequent low and high rates of feed resulting from the pressure regulation type of control.

One argument for motor load control pertains to demand charges for electric power; however, in this case, the demand charge is determined on a 30-min. basis, which means that the kilowatt load for demand is determined by the energy consumption over a half-hour period divided by the time period. With grinding cycles on the order of 2 to 4 min., it can be seen that instantaneous rates of energy consumption are irrelevant with regard to demand charges. The third objective in the direction of increasing capacity and improving pulp uniformity was to control the pressure foot with regard to feed rates to keep a constant relationship between feed and speed without regard to the resulting variability in hydraulic pressures or motor loading.

To accomplish the second and third objectives, it was decided to go to a high pressure hydraulic system so that a small, low volume, fast acting cylinder could be used to actuate the pressure foot. Oil was selected as the hydraulic medium because there is a wide selection of control components available for oil systems while the selection of components for water systems is very limited. Two oil pumps are provided a high volume (25 g.p.m.), low pressure (500 p.s.i.) pump to power the cylinder for retraction and moving the wood into contact with the stone and a low volume (12 g.p.m.), high pressure (2000 p.s.i.) pump to power the cylinder during the actual grinding period of the cycle. These pressures are, of course, adjustable. Constant feed is accomplished with a constant flow valve, which operates on the principle of a constant pressure drop across an orifice independent of upstream pressures. Speed adjustment is made by adjusting the orifice. To power the pressure feet, small diameter, high pressure oil cylinders were mounted inside the castings formerly the

cylinders for the low pressure water powered units as will be explained.

A detailed description of the grinder hydraulic system with circuit diagram (*4*) (Fig. 4) is given in the Appendix.

MACHINE DESIGN PROBLEMS

The machine design problems encountered in applying the small, high pressure hydraulic cylinders to the grinder will be apparent by a re-examination of the standard low pressure, water actuated cylinder shown on Fig. 1. One of the problems experienced with the standard cylinder has been in maintaining the seal at the piston rod packing gland. With low hydraulic pressures and with water as the hydraulic medium, some leakage at this seal can be tolerated. However, with oil as the medium and with much higher pressures, leakage at this point could seriously affect the efficiency of the system as well as contaminate the groundwood pulp. The pressure foot on the original design is rigidly attached to the piston rod with a taper joint. Because of the heavy weight of the pressure foot and eccentricity in the loading applied to it during grinding, a bending moment is developed on the piston rod causing deflections, excessive wear, and binding in the piston rod, guide, and stuffing box.

For economic reasons, every effort was made to retain as much of the original design as possible while applying the high pressure hydraulic oil cylinder to the grinder. To avoid the bending moment in the piston rod, the basic design problem was to support and guide the pressure foot independently of the power unit.

Figure 3 illustrates the resulting design (*5*), a standard hydraulic oil cylinder was selected and was suspended in the middle of and on the centerline of the foot piece. Each end of this cylinder is supported on a pin, but surrounding the pin is a ball and socket type bushing so that effectively the cylinder is supported with a ball joint at each end. Thus, it is impossible to have eccentric or bending loads on the piston rod. This arrangement made it possible to apply effective seals on the piston with assurance of long and satisfactory life. The theoretical life of these nonadjustable seals, based on test data from the cylinder manufacturer, is 350 to 400 years.

The cylinder applies its force directly to the foot piece, and the foot piece in turn is bolted to a guide tube. The guide tube passes back over the cylinder, serves as protection for the cylinder, and also acts as a guard to contain oil should there be a failure of the seal in the cylinder.

The outside of the guide tube is chromium plated to give the surface hardness and wear resistance where it passes through the bronze bearing supporting it just behind the foot piece and to prevent excessive corrosion of this part. The opposite end of this tube is equipped with a bearing shoe which slides on the interior of the housing, which is the casting for the standard hydraulic cylinder normally supplied with this machine.

The front end of the housing is equipped with seals, not for the main purpose of entrapping the lubricant, but rather for the purpose of cleaning the guide tube each time it passes through the bearing to remove foreign material that might be deposited on it and cause scoring or marking of the bearing surface.

The high pressure hydraulic cylinder is equipped with cushions at both ends of the stroke. The cushion on the down going end of the cylinder is provided to reduce shock should the foot piece be accidentally closed when there is no wood in the pocket.

RESULTS OBTAINED

Because the eight grinders feed into a common system, the capacities of the original versus the improved grinders could not be determined from production records. There were also the complications of the need for control of electrical demand, variable down time, the effect of stone diameter,

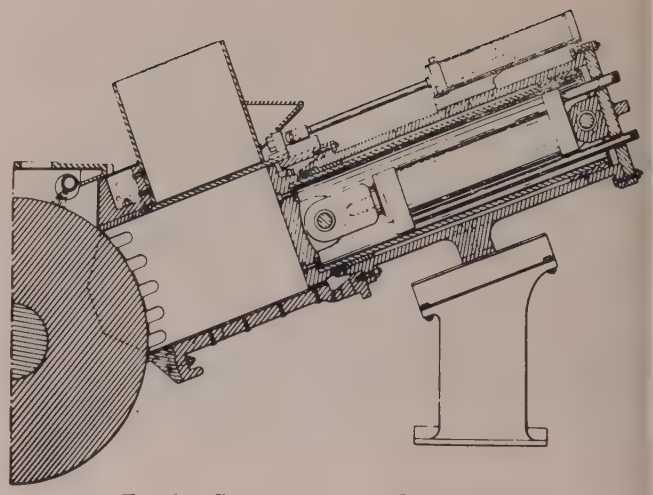


Fig. 3. Section improved power unit

and variable freeness requirements when making different products.

To evaluate the improved grinders, a 7-hr. observation period was planned. There were two groups of observers, one group recorded the pulpwood consumed and the other calculated pulp produced from forming machine production adjusted for broke additives and changes in stock chest levels. The results of the two methods of measurement checked within $1^1/_2\%$ when the data were reduced to average tons of pulp produced per hour.

Neither diameter and condition of the stones nor pulp freeness on each of the eight grinders was checked. The grinders were, however, under the complete control of the operators and were operated in a normal manner. All conditions were typical of those encountered in day-to-day operations. Daily production rates were adjusted for 12% down time to allow for stone changes and mechanical down time. It is felt that the production rates reported are representative of those obtained under operating conditions. The measured capacities are as follows:

Average Grinder Capacity (12% downtime)

Four original grinders—201.6 tons/day or 50.4 tons/day/grinder

Four improved grinders—309.6 tons/day or 77.4 tons/day/grinder

To account for the 50% capacity increase, time studies were taken on the grinding cycles with the following results:

Average Grinder Cycles (minutes)

	Grind	*Retract*	*Delay*	*Total cycle*
Original grinders	2.95	0.54	0.11	3.60
Improved grinders	2.31	0.08	0.13	2.52

From this study, it can be seen that the capacity increase is partly due to the reduction of nonproductive time (reaction time) and partly due to an increase in the grinding rate.

ECONOMIC VALUE OF IMPROVEMENTS

Since pulp and paper industry engineers are usually employed by profit making organizations, their efforts and the resulting innovations must be justified on an economic basis. Also, the risks of failure must be carefully evaluated. In an industry such as this with heavy capital requirements, a new development to increase capacity of a piece of production equipment, if successful, usually pays a handsome return.

From the annual summary entitled, "The Hundred Largest" prepared by the First National City Bank of New York, the 100 largest U. S. corporations employed about 6,200,000 people and did about $124 billion of business in 1957. After deducting the usual costs of doing business, their total net

profit was $9,595,000,000. Of this total, $5,420,000,000 was paid to the stockholders leaving $4,175,000,000 for reinvestment in the business. If a 40 to 60% split between liquid and fixed assets is assumed, these companies were left with $2,405,000,000 for investment in new capacity and production facilities for new products. These are the funds that will make possible the fulfillment of the economists' prediction of a Gross National Product of 700 billion by 1970 from the present 475 billion.

When considered in terms of sales dollars and the efforts expended to acquire them the leverage of the capital dollar is tremendous. In the 100-corporation study cited, $51.60 of sales were required to yield $1.00 for investment in fixed assets.

At current prices, the cost for the third tandem wood grinder line that did not have to be installed at Macon due to improved design and control would have cost $325,000. At $51.60 sales per each new fixed asset capital dollar, the savings on the improved grinder installation was equal to $16,770,000 of sales with regard to contribution toward business growth.

CONCLUSION

The progress of engineers and scientists in the glamour fields of electronics, missiles, and atomic energy is obvious and well publicized. However, the same principles and methods of analysis that lead to breakthroughs in these fields can be daily applied to ordinary work-a-day problems encountered in industry. Basically, the factor in thinking that leads to new developments and progress is a return to fundamentals. Once a problem is recognized and defined in fundamental terms, the battle is usually won. Apples were falling from trees for eons before Newton asked *why* and discovered the law of gravity.

The solution of industrial problems of the type discussed are often taken for granted and go unrecognized, but ultimately they constitute significant contributions to the business organization, the industry, in the aggregate to the economy, and eventually to the consuming public.

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The author takes pleasure in acknowledging his indebtedness to J. D. Lyall, C. Hornberger, and T. Thomas for supplying the design information; E. A. Worm and staff for operating information on the improved grinders; and to Armstrong Cork Co. for permission to publish this paper.

Information regarding licenses to use the patented developments described can be obtained from the Legal Department, Armstrong Cork Co., Lancaster, Pa.

APPENDIX

THE HYDRAULIC CONTROL CIRCUIT

Symbols shown on the circuit diagram (Fig. 4) are the standard graphical symbols of the Joint Industry Conferences, known as the J.I.C. Hydraulic Standards.

The control system for the hydraulic pressure unit 7 for the grinder includes a two-position, three-connection valve 19, which is arranged for manual control and also for automatic air pilot control. The system also includes automatic air pilot controlled valves 20 and 21, which are directional, two-position, four-connection valves, valve 21 being air controlled for movement to each of its two positions. There is also included in the system a pair of mechanically controlled valves 22 and 23, which are directional, two-position, four-connection valves actuated automatically by control rod 9 attached to piston 10 of the pressure unit 7. These serve to control the delivery of air to pilot control cylinder on valves 19, 20, and 21.

The air control system for the pressure unit 8, which

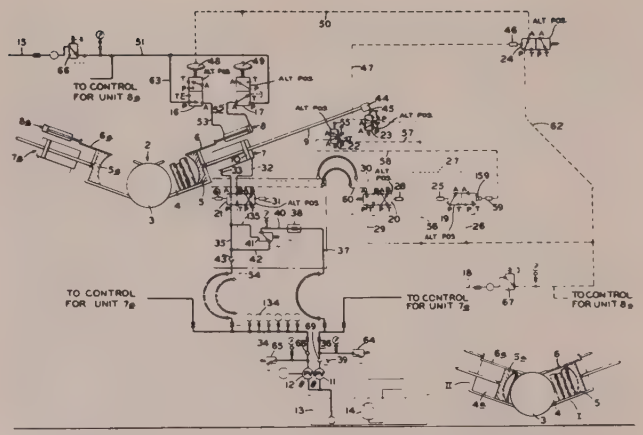

Fig. 4. High pressure hydraulic circuit diagram

actuates the gate 6 includes diaphragm controlled valves 16 and 17 and mechanically controlled valves 22 and 23 previously mentioned. These latter valves have connections for control of the delivery of air to a pilot control cylinder on valve 24, which is an air pilot, controlled, directional, two-position, three-connection valve.

Figure 4 shows the system in an at rest position with bolts of wood charged into the pocket 4 for engagement by the pressure foot 5 for movement into grinding position.

To start the operation, the operator moves the manual control handle 25 of valve 19 to a "start" position. This reverses the position of valve 19 from the position shown in Fig. 4, and control air from source 18 passes through line 26, through valve 19, from pressure port P to port A, then through line 27 to air pilot control cylinder 28 of valve 20, reversing the position of that valve from the position shown in Fig. 4, and connecting ports P and B and ports A and T.

With valve 20 in this reversed position, control air from source 18 flows through line 29, through valve 20 from its port P to port B, to line 30 which leads to air pilot control cylinder 31 of valve 21. This reverses the position of valve 21 and joins ports P and B and A and T. With valve 21 in this position, hydraulic fluid for actuation of the pressure unit 7 will be inletted into the unit above the piston 10 through line 32, and hydraulic fluid will be exhausted from below the piston 10 through line 33.

The system is so arranged that the pressure foot 5 will be advanced quickly with low pressure to bring the wood in the pocket into engagement with the grinding stone 3 to produce a grip on the wood, and then high pressure will be applied to the wood during the grinding phase of the operation to move the wood into the grinding stone at a constant rate. This sequence of operations is accomplished in the following manner:

Fluid under pressure is supplied by pump 12 through line 34 into a group of six, 10-gal. capacity, rubber bag accumulators 134, and then through line 35 to valve 21. With this arrangement, the pump 12 has a relatively small capacity (25 g.p.m.) and by the use of connecting lines of appropriate size from the accumulators, the flow may be increased to 180 g.p.m. to effect rapid movement of the piston 10.

The fluid from line 35 flows into valve 21 and through valve 21 from port P to port B to the line 32 supplying the pressure unit 7 above the head of piston 10. Pump 12 is provided with a governor to permit the pump to be set for a constant pressure output, which may vary over a desired range, say 200 to 500 p.s.i. The governor is provided with a suitable handwheel adjustment to permit such variation of the output pressure as required. With rapid flow of fluid through lines 34, 35, and 32 into pressure unit 7 above piston 10, the movement of the piston to bring the pressure foot into gripping engagement with the wood B in the pocket 4 will be quite

rapid. This initial advance of the piston in the "gripping phase" is equal to about 50% of its full stroke.

Simultaneously, hydraulic fluid from the pump 11 will be supplied under high pressure through lines 36 and 37 to a constant volume, pressure-compensated metering valve 38. This valve operates in accordance with the pressure drop across it to provide for a constant rate of flow through the valve. It delivers hydraulic fluid to the unit 7 at a constant rate, as will be detailed below. The high pressure pump 11 is equipped with a pressure controlled governor. The governor is adjusted by a pneumatic cylinder 39 and a handwheel manual adjustment is provided also to permit operating the governor manually in case of air failure. The capacity of the high pressure pump 11 is low (12 g.p.m. at 2000 p.s.i.) and the governor permits adjustment of pressure from 800 to 2000 p.s.i.

The constant metering valve 38 is adjustable to provide for the desired flow, up to 4 g.p.m., and can be set at any fixed rate of flow within its operating range.

As shown in Fig. 4, the valve 38 may be equipped with a conventional dial gage and a graduated scale and pointer. A manual adjustment with a locking arrangement is also provided on the valve 38 so that it may be set for the desired rate of flow and locked in adjusted position. The desired pressure on the inlet side of the valve 38 will be controlled by the governor on the pump 11.

Metering valve 38 delivers hydraulic fluid to line 40 with leads to a sequence valve 41. The valve 41 is arranged so that the back pressure at which it opens may be varied. This may be adjusted from 200 to 500 p.s.i. back pressure in line 35 through connecting line 135. Thus, when hydraulic fluid acting against piston 10 in the pressure unit 7 brings the wood B in the pocket 4 into engagement with the grinding stone 3 and the pressure on the foot 5 builds up, the forward motion of the piston is arrested and back pressure builds up in lines 32, 35, and 135 until the opening pressure of valve 41 is reached, whereupon it opens and permits hydraulic fluid to flow through metering valve 38 and line 40 and through valve 41 into line 42. A check valve 43 is provided in the line 35 to prevent back flow of the hydraulic fluid into line 34. Thus, the high pressure fluid flows into line 35, through valve 21, from port P to port B, and into line 32 to the upper end of the pressure cylinder 7 above piston 10. The supply of hydraulic fluid to the cylinder above piston 10 is metered by valve 38 to advance the wood into the grinding stone at a constant rate. Since the valve 38 is responsive to the pressure drop across it, it is self-compensating for increases and decreases in pressure required to force the wood into the stone at the desired rate.

As piston 10 in pressure unit 7 moved downwardly to bring the pressure foot 5 into engagement with the bolts of wood, actuator cam 44 on control rod 9 is moved away from the mechanical controller 45 of air control valve 23. This moves valve 23 to a position opposite to that shown in Fig. 4, and port A is now connected to port T. With the valve in this position, air is exhausted from air pilot control cylinder 46 of valve 24 through line 47.

Upon exhausting of air from air pilot control cylinder 46, valve 24 moves to a position opposite to that shown in Fig. 4, and ports A and T are connected. This permits air to be exhausted from the diaphragm 48 and 49, which control actuation of the valves 16 and 17. Exhausted air flows through line 50 to valve 24 and through the valve from ports A to T for exhausting.

When air is exhausted from above diaphragms 48 and 49, spring loaded valves 16 and 17 are reversed from the position shown in Fig. 1, and ports A and T of valve 16 are connected, and ports P and A of valve 17 are connected. In this position, air from source 15 flows through line 51 into valve 17 and through port P to port A and then through line 52 to the top of the pressure unit 8 above the piston therein, and air below the piston is exhausted from the pressure unit 8 through a line 53 and through valve 16 from port A to port T to the atmosphere. Movement of piston in unit 8 in this downward direction moves gate 6 to a closed position, covering the open top of the wood pocket 4, and the gate may be restacked with wood while the pocket grinds out.

As grinding continues, the piston 10 in pressure unit 7 forces the wood into grinding contact with the grinding stone 3 at a constant rate, as previously mentioned, and hydraulic fluid below the piston 10 is exhausted through line 33, through valve 21, ports A and T of which are connected together when the valve 21 is in "grinding position." The fluid passing through valve 21 is received in discharge line 54 through which it is delivered back to the tank 13.

Movement of the piston 10 continues until the actuator cam 44 on control rod 9 engages the mechanical controller 58 of valve 22. When this occurs, the position of the valve is reversed from that shown in Fig. 1, and ports P and A are connected. With the valve 22 in this position, control air from the source 18 is delivered through lines 56 and 57 to valve 22 and passes through the valve from port P to port A to line 58 to air pilot control cylinder 59 of valve 19. When this occurs, valve 19 is reversed to the position shown in Fig. 1 with ports A and T again connected. (It will be remembered that the valve was reversed upon manual operation of the control handle 25 to "start" position at the beginning of the operation.) This exhausts air from air pilot control cylinder 28 of valve 20, through line 27, and through ports A and T of valve 19.

Thereupon, valve 20 returns to the position shown in Fig. 1, and control air now flows from source 18 through line 29 into valve 20 and through its ports P and A to line 60, which supplies air to air pilot control cylinder 61 of valve 21. This returns valve 21 to the position shown in Fig. 4. (Air pilot control cylinders 31 and 61 operate in opposition to one another; cylinder 61 moves the valve 21 to the position shown in Fig. 4, and the cylinder 31 moves the valve to its opposite position.) When the valve 21 is in the position shown in Fig. 4, fluid is supplied by pump 12 through lines 34 and 35 through check valve 43. Fluid supplied through line 35 passes through valve 21, ports P and A, and then through line 33 into the lower end of pressure unit 7, below piston 10. As previously mentioned, pump 12 supplies fluid to the accumulators 134, which are connected to lines of such size that the fluid may be delivered to pressure unit 7 at a relatively high rate, 180 g.p.m., for example, and this effects very rapid retraction of the piston 10 carrying with it the pressure foot 5. Hydraulic fluid above piston 10 is exhausted through line 32 into valve 21 through ports B to T and then through line 54 back to the tank 13.

As soon as piston 10 moves toward its retracted position, actuator cam 44 moves away from mechanical controller 55 of air control valve 22, and air is exhausted from air pilot valve cylinder 59, which controls valve 19. The air is exhausted through line 58 and through valve 22 from ports A to T, which are connected together when mechanical controller 55 is in its normal position as shown on Fig. 1. Air pilot control cylinder 59 is provided with a mechanical holding pawl and detent arrangement 159, which is only overcome by manual operation of control handle 25 of valve 19. Thus, valve 19 remains in a position with ports A and T connected, and the piston 10 continues to move to its fully retracted position. When this occurs, mechanical actuator 45 of valve 23 is engaged, and ports P and A are connected, and air pilot control cylinder 46 of valve 24 is actuated. Air now flows from source 18 through line 62 to port P of valve 24, through valve 24 to port A, and then through line 50 to diaphragm 48 and 49 of valves 16 and 17. This moves valve 16 to a position where its ports P and A are connected and valve 17 to a position where its ports A and T are connected, both as shown on Fig. 4. In these positions, air for retraction of the piston in pressure unit 8, which carries the gate 6 flows from source 15 through line 51, line 63, and through valve 16 from ports

P to A and through line 53 to the lower end of pressure unit 8. The air above the piston in pressure unit 8 is exhausted through line 52 and through valve 17 from ports A to T. Gate 6 is retracted, which permits a charge of bolts of wood positioned on the gate to fall by gravity into the pocket 4 for grinding.

The gate 6 remains open, and the pressure foot 5 remains in its retracted position until the operator reverses the hand lever 25 of valve 19, whereupon the operation is repeated.

It will be clear from the foregoing that should the operator desire to interrupt the automatic operation of the grinder for any reason after the gate closes and the pressure foot is in motion toward the grinding stone, all he needs to do is reverse the manual control handle 25 of valve 19 to a "stop" position, which connects ports A and T, and the gate will automatically open and the pressure foot will automatically retract, and the controls will assume their normal *at rest* position.

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Corrosion of Fourdrinier Wires

JOHN P. GERHAUSER

Fourdrinier wire corrosion in the big majority of the mills is not a major problem. But when it does occur it can be most drastic in cutting down on the life of the paper machine wires. Many mills will operate year in and year out without ever experiencing any corrosion. There are a few mills that are continuously fighting this problem, and, unable to make the necessary changes in the mill equipment or in the furnish, pay for it in short wire life. Some of these mills consider themselves fortunate when they obtain as much as 25% normal wire life. Another group of mills will have periodic cycles of corrosion but for the most part will operate without this headache. At times this corrosion will clear up without the mill making any changes. Sometimes in these mills we are able to determine the whys of this corrosion, but often as not we cannot pinpoint the actual cause.

Corrosion is generally conceded to be electrochemical in nature. That is: a battery type of electric corrosion is set up and it is this current that causes the actual destruction of the metal or alloy. Without going into further detail on the theoretical mechanism of this corrosion we can simplify it into perhaps four or five generally recognized types. Bear in mind, however, that the types I will mention are not sharp divisions in the corrosion field; but one type can and usually does overlap into another division or classification.

The type most generally recognized can be called direct chemical corrosion. This type can be likened to placing a piece of wire cloth into a beaker of acid. The diameters of both warp and shute (particularly the brass shute) are uniformly decreased without any great change, except perhaps for an etched appearance of the wire surface. This might be a good time to mention the alloy compositions commonly used in fourdrinier wires. The industry uses a bronze warp consisting of about 8% tin, 0.3% phosphorous and the balance, copper. The shute alloy is a brass consisting of 15 to 20% zinc with the balance, copper. In an all-bronze wire used when corrosion conditions are severe, we will use a bronze alloy consisting of between 3 and 6% tin, 0.3% phosphorus and the balance, copper.

Temperature, pH, dissolved solids, etc., all affect the rapidity of corrosion, but more about this later. Figure 1 illustrates a brand new wire while Fig. 2 shows this same wire after direct chemical corrosion. In this particular instance

John P. Gerhauser, Director of Technical Service, Appleton Wire Works Corp., Appleton, Wis.

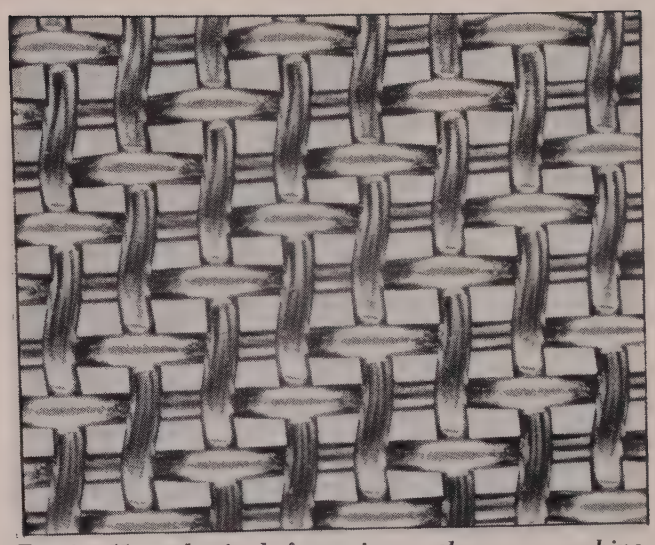

Fig. 1. 55-mesh wire before using on the paper machine, 25×

the warp has corroded to 55% of the original volume, and the shute to 40% of the original volume.

Bimetallic corrosion is the next most commonly occurring type of corrosion. This is a true battery type of corrosion where an electric current is set up between two different metals or alloys. The less noble metal being corroded at the expense of the more noble metal. Perhaps the most extreme couple we can think of is zinc and gold coupled together. With such a couple the zinc would corrode or dissolve at a fantastic rate. Table I shows the galvanic series of metals and alloys such as are commonly found in pulp and paper mills. There have been many of these galvanic series charts published, with slight variations in most of them. This one was prepared by the Battelle Memorial Institute and discussed in the Aug. 27, 1955, issue of *Paper Mill News*. I include three of the noble metals just for comparison. Metals reasonably

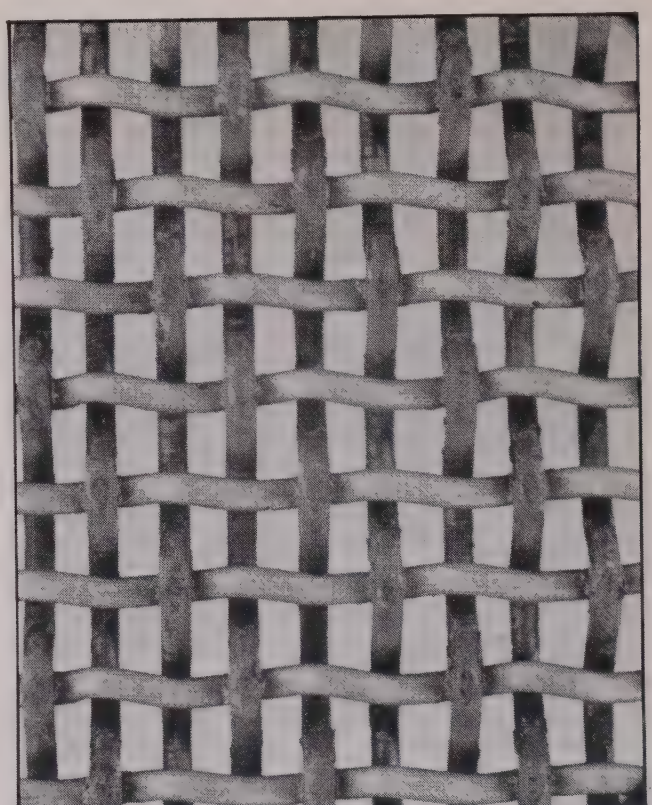

Fig. 2. 55-mesh wire after corrosion; warp corroded to 55% of the original volume; shute corroded to 40% of the original volume

Table I. Galvanic Series of Metals and Alloys

Magnesium	Copper-nickel alloys
Zinc	Monel
Aluminum	Silver solder
Cadmium	Nickel (passive)
Mild steel	Inconel (passive)
Cast iron	13% Chromium stainless (passive)
Lead tin solders	18-18 Stainless (passive)
Lead	18-8-Mo stainless (passive)
Tin	Titanium
Brasses	Silver
Copper	Gold
Bronzes	Platinum

close together in this series will not *theoretically* corrode while the further apart these metals lie the more rapid the electrolytic corrosion. Because of the peculiar phenomenon called polarization, and/or the formation of certain oxide or sulfide films, this polarity can be reversed and the so-called more noble metal suffers corrosion. If the less noble metal is large in area as compared to the more noble metal the corrosion rate might not be fatal; but should the area of the *less* noble metal be smaller than the *more* noble metal the rate of corrosion is tremendously accelerated. Such a situation exists with the silver solder seam. The area of the seam is infinitely small as compared to the area of the entire wire, hence, if the current flows from the seam to the body of the wire, the seam will corrode rapidly. Figure 3 illustrates this condition. Figure 4 shows excessive shute corrosion of the brass alloy. In the case of seam corrosion we sometimes plastic coat the seam area to prevent this condition. Seam corrosion is more apt to occur in an all bronze wire. In all bronze wire we do not have the anodic protection afforded by the brass shute. Apparently under certain conditions the silver alloy of the seam is less noble than the bronze warp and will corrode. When the brass shute alloy is present it apparently will corrode more readily than the solder alloy and in so corroding will give anodic protection to the minute area of the silver solder alloy.

CONCENTRATION CELL OR SOLUTION CELL CORROSION

This type of corrosion has not been given the publicity that I believe it deserves. An electric cell is set up between an area of high concentration and an area of low concentration of an electrolyte; or an area of a high degree of aeration and an area that has little or no aeration; or between areas of different types of electrolytes. In fact, we can reverse the polarity of a zinc-copper couple by putting zinc into a different electrolyte than copper. This type of corrosion is characteristic in cylinder covers. Table II shows the

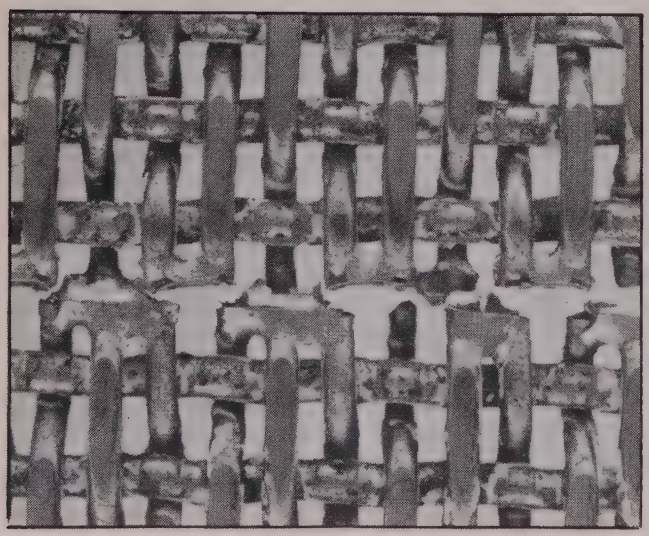

Fig. 3. Seam corrosion as a result of electrolysis, 25×

Fig. 4. Brass shute corrosion as a result of electrolysis, 25×

polarity differences between couples of wire cloth under various conditions as determined in our own laboratory.

Pitting is also quite common in fourdrinier wires particularly at the junction of warp and shute wires. Again we note how this type of corrosion ties in with bimetallic corrosion. Pitting will often occur under a sulfide coating. Copper sulfide is formed on the copper alloy and as this coat builds up to a certain thickness it will flake off leaving fresh metal exposed for futher corrosion. This can set up a vicious cycle of sulfide formation—flaking off—further sulfide scaling, etc. Dezincification is often noted under this sulfide scale. This is a selective dissolving out of the zinc in the brass alloy leaving the composition of the shute much poorer in zinc than the original alloy.

Corrosion fatigue is a variation of the straight chemical type of corrosion. Certain types of film formation protect against further corrosion. Oxide films and even a slight sulfide film can modify the rate of corrosion. With the constant flexing of the wire cloth these films are broken down and the corrosion accelerated. The continual wearing of the warp knuckle on the suction box covers also prevents a protective film being built up on the warp wires. Corrosion lowers fatigue resistance; and fatigue stresses will accelerate corrosion. Intergranular cracking is associated with this type of corrosion.

Intergranular cracking is sometimes associated with mercury amalgams. This is so rare as to hardly warrant discussion except that when it does occur it is most drastic. It is probably the most dramatic of any type of wire corrosion. In the past 15 years we have seen about 10 mercury corrosion cases. Under certain conditions, that we do not fully understand, the mercury in some of the mercury bearing compounds is reduced and will combine with copper alloys in the wire. This amalgam is brittle and the wire will fatigue in a couple of hours.

Table II. Polarity Differences Between Different Couples

Hard alloy	+
Soft alloy	
Small areas	+
Large areas	
Cold	+
Hot	
Quiescent	+
Turbulent	
Clean wire	+
Sulfide coated	
Clean wire	+
Aluminum resinate size filling up	
Dilute electrolyte	+
Concentrated electrolyte	
Different types of electrolytes	

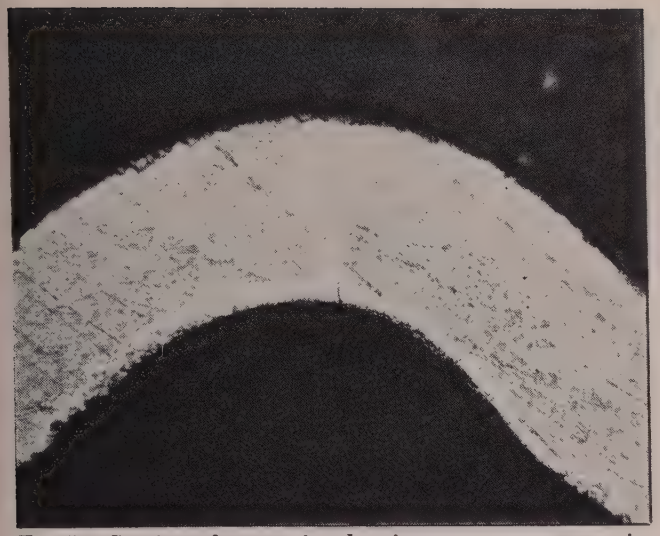

Fig. 5. Section of warp wire showing mercury penetration of short warp knuckle, 250×

Here is a roll of cloth that was sent to me from a local mill by truck. When it left the mill there were no cracks. Riding in the truck for 5 miles resulted in this, every layer of this bundle had cracked. We have found that traces of ammonia or ammonium salts will, in the presence of mercury salts, cause this type of embrittlement. Perhaps a chloramine water treatment will reduce the mercury. This type of corrosion is easily recognized under the microscope and traces of mercury can be detected by a colorimetric test such as we have developed in our laboratory. Figure 5 shows the penetration of the mercury into the short warp knuckle (greatest strained area) and Fig. 6 shows a cross section of this same warp knuckle.

Effect of Temperature

There is a wide variation in the literature on the effect of temperature on the rate of corrosion. However, all authorities apparently agree that it is pretty close to a straight-line

Fig. 6. Cross section of warp knuckle shown in Fig. 5, 250×

Table III. Effect of Variations in pH and Conductivity on Corrosion

Beaker corrosion

pH	*Corrosion, mg./l.*	*Conductivity, microhms*
	pH Adjusted With Alum	
5.8	5.4	215
4.8	15.6	250
4.2	395.0	550
3.5	630.0	2800
	pH Adjusted With H_2SO_4	
6.0	3.2	200
4.8	6.0	200
4.1	12.5	220
3.5	91.0	350

function. Some of the literature states that the corrosion rate is doubled with every 10° rise in temperature. Others state that it is doubled with every 35° rise in temperature. In our laboratory, running beaker tests on wire cloth with paper mill furnishes, we found that the rate of corrosion was doubled with each 25° rise in temperature and that it was an exact straight line function between 60° and 180°F. From observations in mills (particularly glassine mills) I believe that the figure cited above can be accepted as pretty close to being correct.

Effect of Aeration

In beaker tests we have found that aeration tremendously increases the corrosion rate, under all possible conditions. There is no corrective measure that a mill can take to minimize aeration. Certainly a wire running on a paper machine presents an optimum condition for entrained air in the white water.

Effect of pH and Conductivity

The literature and experiments are most confusing, but certainly the further you get away from the pH 7 the more corrosive the white water. We have never been able to develop a satisfactory pH-corrosion curve such as we have with temperature-corrosion, and conductivity-corrosion. Table III shows how variations in conductivity contribute much more to corrosion than does pH. In our minds, conductivity of or concentration of the dissolved solids in white water is perhaps the most critical controllable factor in determining the corrosion rate of fourdrinier wires. We believe a conductivity meter such as is obtainable in most boiler rooms is a most valuable tool in studying corrosion problems. We all know that no two mills are identical and what might be a hazardous condition in one mill might be satisfactory in another mill, hence, the figures I am going to give should not be taken too literally. Somewhere between 600 and 1000 microhms with a normal mill pH could be considered the break in the corrosion curve. In one mill with a pH of 7.3 they found a corrosive condition at 1700 and a noncorrosive condition at 1200 microhms. Chlorides are one of the worst actors, sulfates and sulfites are about the same, while the thiosulfate radical is the worst one we have tested. It had a corrosion rate ten times that of either the sulfate or the sulfite. The break in the corrosion curve for the chlorides is somewhere between 100 and 150 p.p.m.

Assuming you have a good source of water supply, giving you copious quantities of water that is free of dissolved solids, sulfur gases, organic acids from swamps and from the factory pollution so often found in our industrial streams, the complete washing of the pulp fibers will definitely minimize your corrosion. I have in mind a mill that has a completely closed system that has built up the conductivity to 8000 microhms, *that*, to our knowledge, is a world record. The previous high was 3500 microhms. Needless to say, these mills have terrific fourdrinier wire corrosion. The only *out* for a mill

with this high conductivity is to use a nickel plated, tin plated, or plastic coated wire. All types of these wires have done excellent jobs in minimizing the corrosion problems in corrosion mills. The comparative merits of tin- and nickel-plated wires are completely discussed in an excellent article in the September, 1956, issue of *Tappi* magazine.

For the most part we have talked generalities. This is necessary as each mill corrosion problem is an individual problem that can be solved only by a mutual study of the operating conditions in the mill.

Speaking for my company, and I am certain for the entire fourdrinier wire industry, we are most willing to cooperate with any and all mills in studying what we consider our mutual problem "The Corrosion of Fourdrinier Wires."

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Practical Pulp Strength Evaluation Techniques

ALFRED A. MANN

During the course of pulping, bleaching and economic evaluations of different pulps, it has become evident that in order to accomplish the desired analysis of the data, more exact methods of stating pulp strength are required. This means that a single arithmetical value is needed to express the relative strength which a pulp can contribute to a furnish for making paper. By use of relative strength values the substitution ratio of one pulp for another can be determined and the economic value of each stated in comparison to its cost.

Various investigators (*1–5*) have expressed the strength of pulps as single numerical values, determined from a combination of two or more physical characteristics. The method used by Davison (*1*) has appeared admirably suited for the purpose desired and forms the foundation on which this work has been developed. In his plots of tear against burst, and with his lines drawn to represent a constant tear-to-burst ratio, he obtained a fundamental method for determining degree of fiber development. One object of this present work was to determine as closely as possible the tear-to-burst ratio representative of mill refining and beating conditions. A second object was to determine what weight on the bedplate of the laboratory beater gives the best correlation with mill stock treatment. A third object was to keep the strength testing as simple and as economical as possible with respect to time spent in making strength determinations. A fourth object was that of evaluating the practical value of a strength number obtained with the foregoing in mind.

A new stock preparation system was recently installed at Cumberland Mills. This consists of continuous, wide-angle conical refiners designed to give essentially "bruising" rather than "cutting" action. These refiners treat separately the purchased sulfate bleached pulp which is obtained in bales from outside sources and the slush soda hardwood produced at this mill. These two pulps make up the major portion of the fibrous components used for making plain and coated book papers. After all ingredients have been blended together, the final action, which is more "cutting" in nature, is carried out by jordans. During the early operation of this system, the refiners carried out the greatest part of the total refining action, the jordans having been used with very little power. As a consequence it was possible to determine quite closely from the pre-refining of the two pulps what their degree of development must be to meet practical requirements for these book papers.

By plotting tear against burst on a laboratory cooked and bleached sulfate pulp using different bedplate weights on the laboratory beater, it was possible to determine what weight gives the highest tear and burst development at the tear-to-burst ratio within the conditions considered as practicable for mill refining. Using the weight selected, comparisons were made between mill and laboratory treatment of the long and short fibered pulps. Under the discussion of results the value of the correlation obtained may be checked.

Articles by Clark (*6, 7*) and Forman (*8*) brought out the fundamental nature of handsheet apparent density with respect to tear and burst values. The linear relationship of various pulp physical characteristics with density was shown. In the present investigation the various physical tests on handsheets were plotted against sheet density in order to get curves of minimum curvature. By so doing, a minimum of experimental points were required to estimate reliable average lines through the points.

Parsons (*9*) in an article appearing in the literature in 1931 noted practically linear relationships between bursting strength and folding endurance figures when plotted against the fluidities (reciprocal of viscosity) of the corresponding pulps. Wood (*10*) found viscosity tests more useful as a control in digester operation than bleachability tests. Thode (*11*) stated that the bursting strength of unbeaten handsheets is principally a function of but two variables—the specific dye absorption and the cupriethylene viscosity of the pulp. Parmenter (*12*) suggested that a fairly direct relationship might be found between the viscosity values of several shipments of a given grade of pulp obtained from the same pulp manufacturer, and the relative strength characteristics of these shipments.

With all the above ideas on viscosity in mind, it was decided that it would be worthwhile to attempt a correlation between the strength numbers derived above and a viscosity test on each pulp. For routine control purposes a simplified cupriethylenediamine viscosity test was developed and correlated with the relative strength number. For the control of pulping and bleaching in the mill, viscosity tests can be used as a measure of relative strength loss which will make possible the obtaining of a great deal more information with the same number of man-hours involved in evaluation procedures.

Information has been included showing how tear and burst of individual pulps may be combined to predict the corresponding values in a blend of known composition. The additional step required in estimating log fold has been shown. The use of a strength number involving both tear and burst has also been used to calculate the relative strengths of two furnishes in which one pulp was substituted for another of different strength potential. The ratio of the calculated strengths has been compared to the ratio of the measured strengths of the paper off the paper machine. The discussion of results includes a description of these comparisons.

EXPERIMENTAL PROCEDURES

Many of the test methods employed in this work did not follow TAPPI Standards and exceptions are included in the following paragraphs.

Laboratory Beating-Handsheet Forming and Testing

As will be shown in subsequent sections, 2500 g. was selected as the standard weight for the Valley beater. The pulp quantity and consistency specified in TAPPI Standard T 200 were used. Dried pulps were soaked overnight and then

Alfred A. Mann, Assistant Pulp Mill Superintendent, S. D. Warren Co., Cumberland Mills, Me.

pulped using a nonstandard stirrer with a slotted disk agitator blade. Slush pulps were not disintegrated, but all pulps have been beaten 5 min. with no weights on the bedplate prior to the start of the beating with weights. The standard temperature of the stock during the beating was not followed; neither were the beating surfaces calibrated with abrasive. Only four samples of 1500 ml. each were withdrawn at 1, 5, 15, and 40 min. after starting the beating process with the 2500-g. weight applied.

The Noble and Wood sheet machine was used for making handsheets. The recommendations of the manufacturer were followed in using this equipment. Since sheet density is appreciably affected by wet pressing (*3*) the calibration of the wet press weights has been done at least once a week. The sheets were made to a basis weight specification of 42.7 ± 1.7 lb. (m.-f. basis) for a 25 × 40 −500 ream. They were conditioned for at least 1 hr. in a humidity room at 73°F. and 50% R.H. before running physical tests. Prior to this the sheets were conditioned in an air-tight humidity box with a saturated solution of potassium carbonate in a plastic tray in the bottom of the box. After overnight conditioning in the humidity box the sheets were weighed and the basis weight determined allowing for the predetermined equilibrium sheet moisture.

Only four sheets instead of five were used for physical testing. Five calipers on four thicknesses were made on the sheets before cutting test pieces. These calipers were used to calculate apparent density of the handsheets. The strips for tear testing were cut adjacent to the diagonal of the square sheets (8 × 8 in.). Strips adjacent to the tear strips were used for the Schopper fold test. The corner pieces were used for burst testing. Five tears were made on four thicknesses for long-fibered, and on eight thicknesses for short-fibered pulps. Eight burst and four fold tests were made on each set of sheets. Except for the differences noted, physical testing was done in accordance with TAPPI Standards T 220, T 403, T 411, and T 423.

Fiber Length Index

A modification was made of the method of de Montigny (*13*) for determining a fiber length index (FLI). Since the British sheet machine was not available for use, the grid was attached to the bottom of a copper cylinder (6-in. tubing) which was placed inside a copper can of approximately $6^1/_2$ in. inside diameter. After filling the inner cylinder to a depth of about 10 in. with water, 10 g. of disintegrated pulp was poured in and the level adjusted to 14 in. Then the contents were stirred with a stirrer patterned after the one used with the Noble and Wood sheet machine. A belt formed from a piece of press felt was attached to the top of the cylinder and the other end placed between the press rolls of the sheet machine so that the cylinder would be pulled up through the pulp suspension at the same velocity for each determination. The fiber length index was taken as the grams of fiber collected on the grid per 10 g. of fiber originally present in the fiber suspension added to the inner cylinder.

Simplified Viscosity Test

A simplified cupriethylenediamine viscosity test was devised. It was realized that the method so developed would permit rapidity and simplicity of testing at the expense of some precision.

The viscosity test was conducted in the following manner. An ordinary 10 ml. volumetric pipet was selected as a viscosity measuring device. Using a file, marks were scratched just above and below the bulb. The delivery of the solution from the top mark down to the bottom mark was taken as the delivery time in each case. The pipet was calibrated under constant temperature conditions using four different aqueous solutions of glycerine (C.P. grade) of measured specific gravity. Viscosity values were obtained for these glycerine solutions from Lange's "Handbook of Chemistry." The range was from 5.4 to 84.0 cp. in nearly equal spacing between values. The delivery time at 77°F. was plotted against the corresponding viscosity value and a smooth curve drawn through the points. The delivery times at different temperatures on either side of 77°F. were obtained on water and on two pulp solutions of low and medium viscosity value and a temperature correction chart set up. In carrying out determinations on pulp solutions of unknown viscosity, successive checks were made until the delivery time, corrected to 77°F., agreed within 1% of the preceding test value. The final corrected delivery time was used to select the corresponding viscosity value in centipoises from the calibration curve.

The cupriethylenediamine solution was stored in the bottle in which it was received. The bottle was equipped with a two-hole rubber stopper, glass tubing, rubber tubing, a drying tube and clamps so that the solvent could be removed through a 15-ml. pipet. At the same time that the solvent was being removed, air was being drawn into the top of the bottle through Drierite and Ascarite in the drying tube. Afterwards all entrances to the bottle and to the drying tube were stopped-off with the clamps. As a further guard against decomposition of the solution a piece of clean copper wire was placed inside the bottle.

In preparing pulp solutions, standard handsheets from the 1-min. beating were used. A piece of the sheet was placed in the oven at 221°F. (105°C.) for 3 min., then 0.15 g. of pulp weighed out quickly, torn into small pieces and placed in a 50-ml. graduate under a copper stirring rod made as shown in TAPPI Standard T 230, the rod being clamped in the chuck of a variable speed stirrer. With the stirrer running at a slow speed, 15 ml. of water followed by 15 ml. of solvent were pipetted into the graduate and stirring allowed to continue until the pulp was dispersed. The time varied from 3 to 30 min. depending on the viscosity of the pulp. The resulting pulp solution was approximately $^1/_2$% pulp. Tests on eight different pulps covering the range of viscosities encountered in this work were tested by this simplified method and at the research laboratory in accordance with TAPPI Standard T 230 using a viscosity pipet. The comparison of the simplified and standard method appears in Fig. 1. It may be noted that a couple of "wild" points appear near the center of the curve. It is felt that something was definitely wrong with these two points because the others appear to lie along the average curve very nicely.

Pulping and Bleaching

Experimental pulps were cooked in a pilot digester of approximately 10 cu. ft. capacity. The digester was cooked

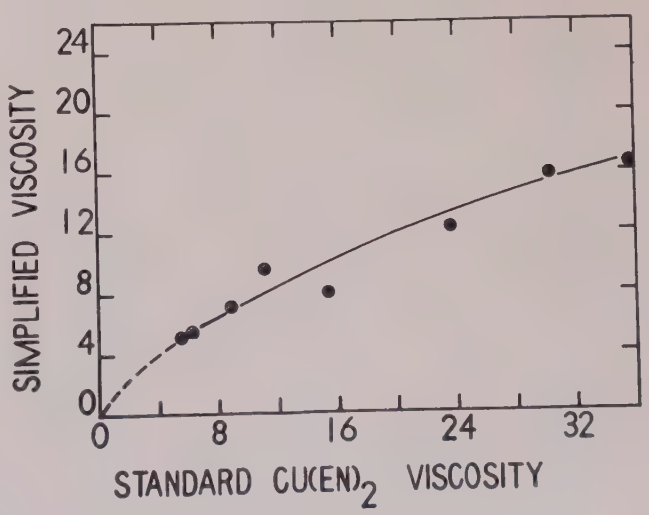

Fig. 1. Simplified vs. standard cupriethylene viscosity

Table I. Slush Sulfate Pine 85706—Strength at Different Bedplate Weights

Bedplate weight, g.	Beating time, min.	TAPPI tear factor	TAPPI burst factor	$(T^a \times B^b)^{1/2}$	Av. $(T \times B)^{1/2}$
1500	1	195	31	78	
	7	130	46	77	
	15	115	58	82	77
	35	95	62	77	
	75	82	73	77	
	120	70	70	70	
2500	1	154	32	70	
	5	146	45	81	
	10	119	56	82	75
	30	86	68	77	
	65	74	71	73	
	105	66	71	69	
3500	1	139	31	66	
	5	127	47	77	
	10	104	56	77	75
	25	93	65	78	
	55	88	75	81	
	90	70	72	71	
4500	1	170	38	81	
	4	121	47	76	
	9	113	63	85	78
	20	96	64	79	
	40	78	76	77	
	75	67	76	71	
5500	1	119	37	66	
	3	129	49	80	
	8	119	58	83	79
	15	113	74	92	
	30	83	80	82	
	60	68	74	71	

[a] T = tear.
[b] B = burst.

with direct steam and had forced circulation withdrawing liquor from behind a suction strainer in the bottom cone and discharging the liquor into the top through a strainer basket, which sprayed the liquor over the top of the chips.

Bleaching of sufficiently large samples to permit beater evaluations was carried out in covered plastic containers. Mixing and agitation was done by hand. The chlorination stage was conducted at approximately 3% consistency (moisture-free basis). The other stages were done at about 6%. Bleaching was done using conventional conditions of time, temperature and pH. Brightness tests were made on pulp sheets formed on the Noble and Wood sheet machine using tap water. The Photovolt meter was used to test brightness of the handsheets. It is estimated that TAPPI brightness would probably be about two points higher.

DISCUSSION OF RESULTS

Laboratory versus Mill Beating

Table I includes the test data obtained on a laboratory

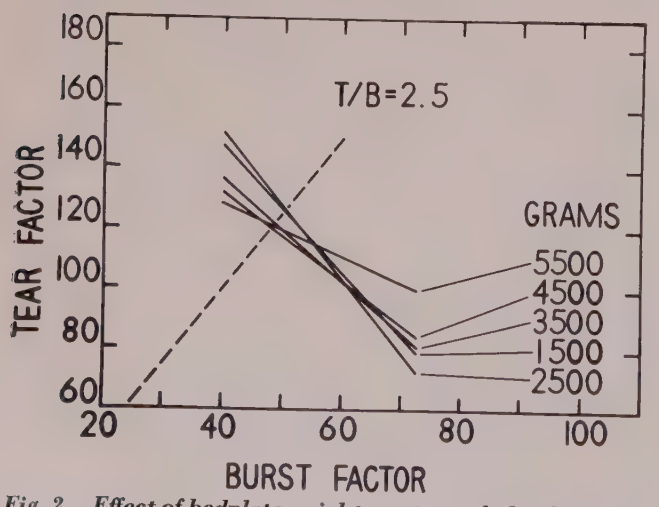

Fig. 2. Effect of bedplate weight on strength development

Table IIa. Bleached Softwood Sulfate

Date	Apparent density g./cc.	TAPPI tear factor	TAPPI burst factor	Tear/burst
		Mill Refining		
20 Oct. 58	0.520	157	65	2.42
21 Oct. 58	0.490	169	55	3.07
22 Oct. 58	0.500	169	58	2.91
24 Oct. 58	0.513	152	55	2.76
27 Oct. 58	0.505	161	55	2.92
29 Oct. 58	0.532	144	63	2.29
30 Oct. 58	0.505	154	59	2.61
31 Oct. 58	0.505	142	60	2.36
1 Nov. 58	0.515	158	59	2.68
7 Nov. 58	0.503	147	56	2.62
Average	0.509	155	59	2.63
		Valley Beater		
27 Mar. 58*	0.493	125	48	2.60
8 Jul. 58*	0.520	146	56	2.60
20 Aug. 58**	0.497	143	55	2.60
20 Aug. 58†	0.510	142	54	2.60
4 Oct. 58†	0.521	153	58	2.60
5 Dec. 58*	0.500	135	51	2.60
11 Dec. 58	0.508	146	55	2.60
13 Dec. 58	0.495	146	56	2.60
15 Dec. 58	0.498	142	54	2.60
17 Dec. 58	0.521	138	58	2.60
Averages	0.506	142	55	2.60

* Dried pulp from bale kept since 1951.
** Undried pulp fresh as of date noted.
† Undried pulp from different source.

cooked and bleached sulfate pine pulp beaten using different bedplate weights on the Valley beater. Samples were taken at the six different times noted, to cover the practical range completely. Column $(T \times B)^{1/2}$ was included to show how nearly constant this value is in the middle (or practical) range of beating shown here.

The portion of the data for each bedplate weight for which a straight line may be estimated as an average of a plot of tear versus burst was included graphically in Fig. 2. The numbers in the lower right hand corner of the figure refer to the various bedplate weights used. A dotted line representing a constant ratio between tear and burst equal to 2.5 was drawn in. From this graph it may be seen that the 2500-g. weight gives the highest tear and burst at the specified ratio to be shown later as representative of mill pre-refining.

In Table IIa and IIb may be seen the comparisons between

Table IIb. Comparison of Mill Refining and Valley Beater at 2500 Grams on Bedplate Soda-Hardwood

Date	Apparent density g./cc.	TAPPI tear factor	TAPPI burst factor	Tear/burst
		Mill Refining		
21 Oct. 58	0.463	68	33	2.06
22 Oct. 58	0.450	75	30	2.50
24 Oct. 58	0.463	72	34	2.12
27 Oct. 58	0.481	67	33	2.03
29 Oct. 58	0.481	72	29	2.48
30 Oct. 58	0.456	63	33	1.91
31 Oct. 58	0.446	66	29	2.27
1 Nov. 58	0.444	75	31	2.42
6 Nov. 58	0.451	69	30	2.30
7 Nov. 58	0.447	69	33	2.09
Averages	0.458	70	32	2.19
		Valley Beater		
3 May 58	0.458	51	32	1.59
5 May 58	0.458	55	39	1.41
13 May 58	0.458	56	28	2.00
17 May 58	0.458	58	24	2.42
4 Jun. 58	0.458	78	27	2.88
24 Sep. 58	0.458	63	28	2.25
25 Sep. 58	0.458	73	26	2.80
27 Sep. 58	0.458	76	31	2.45
8 Oct. 58	0.458	70	30	2.33
10 Oct. 58	0.458	73	32	2.28
Averages	0.458	65	30	2.17

mill pre-refining equipment and the laboratory beater when comparing strength properties of standard handsheets. The comparisons are made for both the purchased bleached sulfate coniferous pulp and the slush hardwood soda pulp which receive the pre-refining treatment separately. At the time these tests were made very little subsequent stock treatment was done in the jordans.

Calipering of handsheets made from samples of a mill refined, paper machine furnish taken from the headbox on the machine, triple washed to remove filler and other non-fibrous materials, has yielded apparent density figures of 0.465 to 0.477. This furnish contained approximately 40% long fiber and 60% short. The average figures for mill refined, hardwood and bleached sulfate shown in Table IIb × IIa were 0.458 and 0.509 respectively for the density of handsheets. Using these figures the density should have been 0.478 which agrees very closely with the figures obtained on the blend from the paper machine headbox. It is believed very likely that the triple washing of the headbox stock would have a tendency to remove fines, resulting in a somewhat lower density. From these comparisons it is felt that the degree of refining represented in Table IIb is an accurate approximation of total mill fiber treatment.

As will be shown later, decreasing the tear-to-burst ratio further within the possible limits of practical requirements will not affect the relative strength of two different pulps to any appreciable degree. All factors taken into consideration, the laboratory beater using a 2500 g. bedplate weight appears to give results very similar to those obtained with the pre-refining equipment. A tear-to-burst ratio was taken at 2.5 for coniferous pulps and at 2.2 for mill soda hardwood from these data as being representative of overall mill stock preparation.

Table III. Cooking, Bleaching and Strength Data—Experimental Alkaline Pulps

Cook no.	*Bleaching sequence*	*Cl_2 demand, %*	*Photovolt brightness*	*TAPPI tear factor*	*TAPPI burst factor*	*Log fold (Schopper-double folds)*
		Whole Logwood				
65813	CEHHH	10.6	76.0	124	50	2.57
65813	CESSS	10.6	83.0	140	56	2.72
65817	CEHH	12.8	78.5	133	53	2.65
65817	CESS	12.8	77.5	151	60	2.87
75809	CEHH	13.2	82.5	115	46	2.65
75809	CESS	13.2	76.5	141	56	2.93
75811	CEHH	9.4	78.0	116	46	2.66
75811	CESS	9.4	79.5	140	56	2.87
75815	CEHH	11.4	80.0	125	50	2.61
75815	CESS	11.4	80.5	142	57	2.77
75823	CEHH	7.3	82.0	97	39	2.14
75823	CESS	7.3	83.5	130	52	2.64
75829	CEHH	6.3	80.0	103	41	2.32
75829	CESS	6.3	79.0	122	49	2.54
75831	CEHH	6.8	82.5	103	41	2.31
75831	CESS	6.8	82.0	135	54	2.82
85804	CEHH	9.8	80.0	122	49	2.85
85804	CESS	9.8	79.5	144	58	2.94
115805	CESS	12.8	78.0	148	59	2.82
		Slabwood				
55828	SSSSS	18.0*	72.5	162	65	3.02
65804	CEHH	12.5	79.0	137	56	2.70
65804	CESS	12.5	79.5	146	59	2.93
65809	CEHH	12.4	79.5	127	51	2.80
65809	CESS	12.4	78.5	155	63	2.87
65811	CEHHH	10.7	79.0	133	54	2.69
65811	CESSS	10.7	83.5	153	62	2.98

Cook no.	*Strength no.*	*Fiber length index*	*$Cu(EN)_2$ visc., cp.*	*Log visc.*	*Log log visc.*
		Whole Logwood			
65813-H	25.2	3.0	6.4	0.806	−0.095
65813-S	27.8	2.8	8.0	0.902	−0.045
65817-H	26.6	2.4	7.6	0.880	−0.056
65817-S	29.6	2.7	10.2	1.008	+0.003
75809-H	24.1	2.8	5.8	0.763	−0.118
75809-S	28.6	2.9	9.6	0.982	−0.009
75811-H	24.2	2.6	6.1	0.786	−0.106
75811-S	28.2	2.8	8.5	0.929	−0.033
78515-H	25.4	3.1	6.1	0.785	−0.106
75815-S	28.2	3.0	8.4	0.923	−0.035
75823-H	20.1	2.9	4.5	0.653	−0.186
75823-S	26.0	2.9	6.0	0.778	−0.110
75829-H	21.4	2.3	4.8	0.681	−0.167
75829-S	24.8	2.3	6.2	0.792	−0.102
75831-H	21.4	2.3	4.6	0.662	−0.179
75831-S	27.4	2.4	6.3	0.798	−0.098
85804-H	25.8	2.3	6.0	0.778	−0.110
85804-S	29.1	2.5	8.6	0.934	−0.030
115805-S	29.2	...	11.1	1.045	+0.019
		Slabwood			
55828-S	31.7	2.9	11.5	1.060	+0.025
65804-H	27.5	3.1	6.9	0.838	−0.077
65804-S	29.4	3.4	8.4	0.923	−0.035
65809-H	26.3	3.2	6.8	0.832	−0.080
65809-S	30.4	3.1	9.9	0.995	−0.003
65811-H	26.8	3.6	6.1	0.784	−0.106
65811-S	30.5	3.5	8.4	0.923	−0.036

* Estimated.

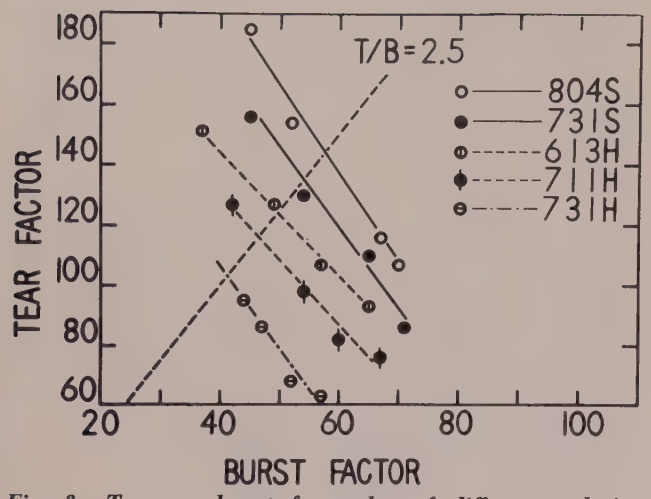

Fig. 3. Tear vs. burst for pulps of different relative strength

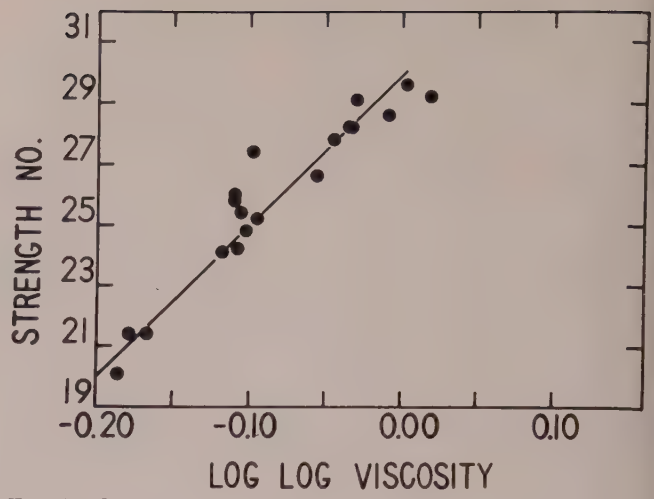

Fig. 5. Strength no. (including fold) vs. log log viscosity

Physical Properties of Experimental Pulps

In Table III appear bleaching and physical testing data for experimental alkaline process pulps from whole log pine (*Pinus strobus*) and from pine slabwood. Certain features of these data appear in Figs. 3, 4, 5 and 6.

The code for the bleaching sequence is as follows: C-chlorination, E-caustic extraction, H-hypochlorite (calcium), and S-sodium chlorite acidified with acetic acid. The chlorine demand is the total percentage of chlorine consumed in reaching the brightness stated based on the moisture-free weight of pulp. The total equivalent bleach required for chlorite bleaching was assumed to be the same as for hypochlorite bleaching. The method of bleaching with chlorite permitted the loss of considerable chlorine dioxide as a gas, making accurate consumption of this chemical difficult to measure. All values for tear, burst, fold, and fiber length index (FLI) were taken at the point of laboratory refining at which the tear-to-burst ratio was 2.5. The log of fold is the average of four determinations of Schopper fold (double folds) at each beating period, the curve being extrapolated to the proper point of refining. The strength number was determined by extracting the cube root of the product of tear, burst and log fold. The $Cu(EN)_2$ viscosity is the simplified viscosity value described earlier. The last two columns show the single and double logarithms of the viscosity value.

Figure 3 illustrates a plot of tear against burst of five different, experimental, whole log pulps of different strength potential. The relative strength may be expressed as either the tear or burst value at the point where each line is intersected by the line of constant tear-to-burst ratio of 2.5, or it may be expressed as the square root of the product of the tear value times its corresponding burst value. The use of the tear value at the point of intersection has been used for the correlation of strength and viscosity. It may be seen from the fact that the lines representing the tear versus burst relationship for these pulps are nearly parallel, that the comparison ratio can be shifted to either the left or right without seriously affecting the relative strength of one pulp compared to another.

If the relative strength of the various pulps from whole log pine are plotted against the corresponding viscosity values, then it requires a line of considerable curvature to approximate the points. The curve indicates that at the highest viscosity the strength value has become practically constant with increasing viscosity. If the strength values are plotted against the log of viscosity, the line can be straightened some; and using log log viscosity, a straight line is an acceptable approximation as shown in Fig. 4. The tendency for curvature is still there, but much reduced.

If the data for tear and log log viscosity from Table III are plotted for these pulps from slabwood, then a straight line approximation of the points could be drawn of equal slope to the line shown in Fig. 4, but displaced upward from it. This shows that at the same viscosity level, the slabwood produces a pulp of higher relative strength. The slabwood pulps also exhibited higher fiber length indices, increased fiber length evidently being a real factor in the increased strength of pulps produced from the sapwood region of the tree. Other factors may influence the superiority of sapwood pulps, but this investigation gives no idea what they may be other than what the work has shown, that higher yields do result from slabwood.

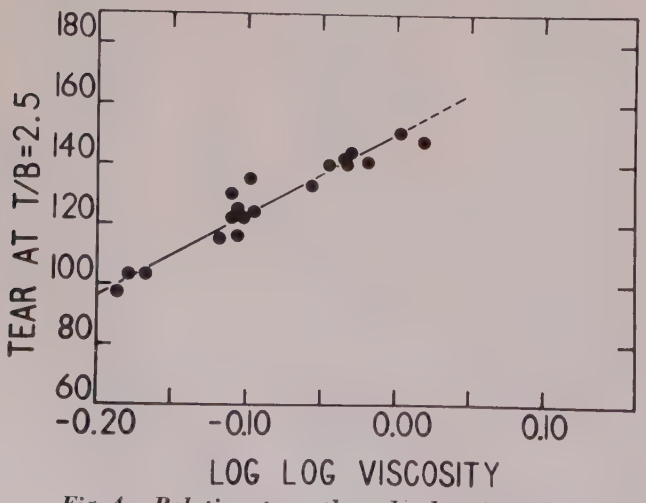

Fig. 4. Relative strength vs. log log viscosity

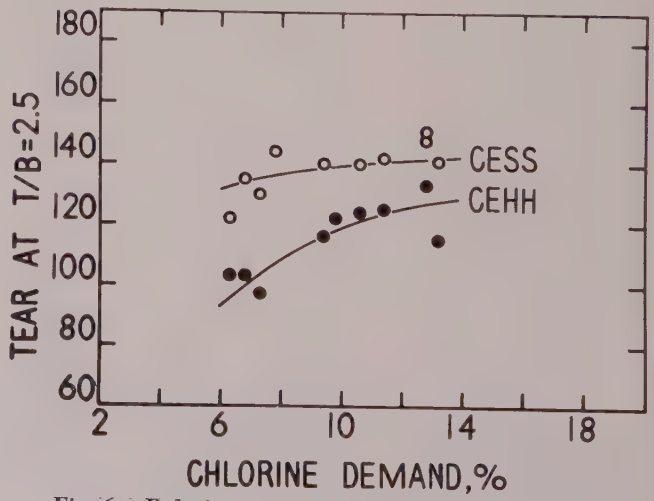

Fig. 6. Relative strength vs. bleach requirement

Table IV. Physical Tests for Component Pulps and Blends Including Softwood, Hardwood and Broke

Pulp	*Broke*	*Hdw*	*Soft-wood*	*No. 1 blend*	*No. 2 blend*	*No. 3 blend*	*No. 4 blend*	*No. 5 blend*	*No. 6 blend*	*No. 7 blend*	*No. 8 blend*	*No. 9 blend*	*No. 10 blend*
Broke %	100	...	...	...	...	...	15	15	30	30	50	50	50
HW %	...	100	...	75	50	25	25	60	20	50	15	35	...
SW %	...	...	100	25	50	75	60	25	50	20	35	15	50
TAPPI tear factor	107	105	180	122	131	154	153	134	141	109	141	136	156
TAPPI burst factor	33	29	54	34	39	49	44	35	44	34	40	32	43
Fold (Schopper)	37	11	610	48	140	450	370	57	250	43	193	42	273
Log fold	1.57	1.04	2.79	1.68	2.15	2.65	2.57	1.76	2.40	1.63	2.29	1.62	2.44
Linear shrinkage, %	4.6	4.3	3.3	3.8	3.7	3.3	3.7	4.1	3.6	4.1	4.0	4.3	3.8
C.S.f., ml.	255	429	610	489	535	579	538	487	486	435	417	398	452
Gurley dens., sec.	24	4	6	4	6	6	6	6	10	8	14	8	12
Basis wt. lb./ream	44.4	46.1	41.0	45.3	43.5	45.3	42.7	44.4	44.4	44.4	44.4	43.6	41.0
Photovolt bright.	69.5	74.5	76.0	74.0	74.5	75.5	76.0	73.0	72.0	71.5	72.0	72.0	71.0
Tear/burst	3.2	3.6	3.3	3.6	3.4	3.1	3.5	3.8	3.2	3.2	3.5	4.2	3.6
Tear/burst av.		3.4						3.5					

If log fold is included in the strength number as in Fig. 5, then the correlation is not improved at all, in fact it appears to be worse. Owing to this fact and the difficulty of predicting folds of blends of long and short fibered pulps from the values of the component pulps, it was not considered worthwhile to include fold in the determination of a relative strength value.

Figure 6 illustrates the use of the relative strength value in obtaining a visual analysis of the effect of the mildness of the cook and the type of bleaching sequence used. This graphical illustration shows very conclusively the beneficial effects of chlorine dioxide bleaching on strength retention.

The excellent correlation between the relative strength value, as determined by the tear at the specified ratio of tear-to-burst of 2.5, and a function of viscosity gives added confidence in the use of either value alone. This relationship makes possible the use of viscosity tests in routine control testing of pulping and bleaching whereby a great deal of data can be obtained with a minimum of effort, at the same time furnishing an idea concerning the relative strength changes resulting from changing viscosity value.

Pulp Blends

Data appearing in Tables IV, V and VI show the results of comparing the measured values for the various physical characteristics of a blend of pulps against calculated values based on the tests for the individual pulps. The first three columns in Table IV give the data for the three component pulps beaten to approximate a tear-to-burst ratio of 3.5. At the time these tests were made it was thought that this ratio more nearly approximated mill conditions. The ten columns marked "No.—Blend" give the tests on blends of the three pulps in the proportions shown. The tests were made on standard handsheets prepared from the mixtures. Only tear, burst and fold were used for comparing calculated and measured values, but other data have been included for information. The shrinkage test gives the average percentage linear shrinkage of handsheets when dried in the air under no restraint.

The calculated values were obtained by multiplying the test for each individual pulp by its decimal fraction of the total blend, then taking the sum of these products. The column marked "% from calcd." refers to the per cent difference between measured and calculated based on the calculated value. "$\bar{d}$" is the average percentage difference and σ is the standard deviation of the percentage difference.

Table V. Comparison of Calculated and Measured Physical Tests on Blends of Softwood, Hardwoods and Broke Pulps

Blend no.	1	2	3	4	5	6	7	8	9	10	$\bar{d}$	σ
Tear calcd.	124	143	161	151	124	144	121	132	117	144		
Tear measured	122	131	154	153	134	141	109	141	136	156		
% from calcd.	−1.6	−8.4	−4.3	+1.3	+8.1	−2.1	−9.9	+6.8	+16.2	+8.3	+1.4	8.3
Burst calcd.	36	42	48	45	36	43	35	40	35	44		
Burst measured	34	39	49	44	35	44	34	40	32	43		
% from calcd.	−5.6	−7.1	+2.1	−2.2	−2.8	+2.3	−2.9	0.0	−8.6	−2.3	−2.7	3.6
Log fold calcd.	1.58	2.14	2.65	2.48	1.70	2.37	1.69	2.19	1.73	2.53		
Log fold meas.	1.68	2.15	2.65	2.57	1.76	2.40	1.63	2.29	1.62	2.44		
% from calcd.	+6.0	+0.5	0.0	+3.5	+3.4	+1.3	−3.6	+4.4	−6.8	−3.6	+0.5	4.1

In calculating the log fold of each blend, a long-fiber factor was multiplied into each product of individual pulp log fold times its decimal fraction of the blend, in the case of broke and purchased pulp since these contain long fiber. Table VI shows the factors used depending on either the percentage of long fiber in the broke, or for the purchased pulp based on the percentage of long fiber this contributes to the total blend. These factors may not be precise for all situations, but they do fit these data remarkably well and point out the different, proportionate influence long fiber has on the fold of a blend compared to short fiber.

Carrying the idea of calculating strengths of blends a step further, Table VII shows the results of predicting the ratio of strengths of two paper furnishes (designed to produce the same grade) by calculations based on the relative strength numbers of the component pulps. In each case the standard purchased sulfate pulp (no. 1 long fiber) was replaced in the second furnish of the pair by an inferior long-fibered pulp, but in greater proportions in order to arrive at the same strength in the paper. The first part of the Table shows the physical values for the five pulps involved. The next section shows the results obtained in calculating the square root of tear times burst for the first two furnishes accompanied by the average values obtained for both furnishes from

Table VI. Long Fiber Content versus Long Fiber Factor Used in Calculating Log Fold of Blends

Long fiber content	0	10	20	30	40	50	60	70	80	90	100
Long fiber factor	1.00	1.08	1.12	1.15	1.16	1.16	1.16	1.15	1.12	1.08	1.00

Table VII. Comparison of Calculated and Measured Strengths of Paper Furnishes

Basic Data on Pulps Used

	Pulp designation				
	No. 1 Softwood	*No. 2 Softwood*	*No. 3 Softwood*	*Broke*	*Hardwood*
Refined by	Mill equip.	V.B.*	V.B.	V.B.	Mill equip.
Handsheet density, g./cc.	0.509	0.478	0.497	0.453	0.458
TAPPI tear factor	155	95	127	90	70
TAPPI burst factor	59	38	51	36	32
(Tear × Burst)$^{1}/_{2}$	95	60	81	57	47
Tear/burst	2.6	2.5	2.5	2.5	2.2

Furnish composition and ratio of strength for paired furnishes

Furnish no.	*Composition*	*Calcd. $(T \times B)^{1/2}$*	*Measd. $(T \times B)^{1/2}$*	*Calcd. ratio*	*Measd. ratio*
1	24% No. 1 SW 14% Broke 62% HW	60	$(82 \times 30)^{1}/_{2} = 50$	1.11	1.14
2	42% No. 2 SW 14% Broke 44% HW	54	$(73 \times 27)^{1}/_{2} = 44$		
3	32% No. 1 SW 68% HW	62	$(65 \times 26)^{1}/_{2} = 41$	0.99	1.00
4	48% No. 3 SW 52% HW	63	$(64 \times 26)^{1}/_{2} = 41$		
5	75% No. 1 SW 25% HW	83	$(102 \times 44)^{1}/_{2} = 67$	1.03	1.06
6	100% No. 3 SW	81	$(102 \times 39)^{1}/_{2} = 63$		

* Valley Beater.

actual measurements on the paper. The amount that the actual measured values drop from the calculated values depends on several factors, but since the relative strength of one furnish against the other is the only value of interest, the absolute difference between calculated and measured values is only of academic concern.

The percentage compositions and the type of fiber used have been specified for furnishes 3–4 and 5–6. The ratio between the strengths of each pair of furnishes were included for both calculated and measured values. The remarkable similarity of the relative strength ratios obtained by calculation and measurement indicates that the relative strength number can be used successfully to predict the substitution ratio of one pulp for another, to produce paper of the same strength. This applies to the combination of tear and burst; but fold is more difficult owing to previously shown differences between the influence of short and long fibered pulps in blends.

CONCLUSIONS

Two thousand five hundred grams was found to be theoretically the most efficient bedplate weight for use with the laboratory beater for tear and burst development at a point of fiber preparation considered equivalent to mill conditions for making book papers. The analysis of hardwood soda pulps and purchased bleached sulfate coniferous pulps using this weight on the bedplate gave results which correlated well with mill pre-refining equipment at maximum practical pre-refining.

For making plain and coated grades for book publishing, overall mill refining accomplishes the development of tear and burst in long fibered pulps to a point where the ratio is approximately 2.5 and for hardwood soda pulps the ratio is approximately 2.2.

A relative strength number was defined as the tear factor at the point of refining where the ratios stated in the preceding paragraph were met. The relative strength numbers for various experimental pulps, pulped and bleached in essentially the same manner from the same wood source, were plotted against a function of the corresponding cupriethylene viscosity values. The excellence of the resulting correlation attests to the validity of both methods for expressing pulp strength. By the use of log log viscosity a linear relationship with strength resulted, suitable for use in determining relative strength in routine control testing by use of viscosity tests. The viscosity test used was a simplified procedure based on TAPPI Standard T-230 and gave results relative to the standard method but not equal.

It has been shown that for pulps given the stock treatment as specified, the tear or burst of a blend may be accurately calculated by taking a weighted average of the tear or burst values for the individual component pulps. For calculating the log fold of a blend, long fibered pulps contribute to more log fold in the blend than the proportion and the log fold value of the individual long fibered pulp would indicate. The same calculations may be applied to two furnishes designed to produce the same grade of paper, when one long fibered pulp is substituted for another; and the ratio of the calculated strength based on a combination of tear and burst for the two furnishes will very closely approximate the ratio of actual measured strength of the paper.

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Organized Lubrication—A Case Study

J. A. BOX, JR.

As a background to the organization of our lubrication department, may I first tell you something of the physical location of the various parts of our plant (Fig. 1).

There are a total of seven paper machines in the plant. Four machines are located in the area designated as the board mill, and the remaining three are in the sulfate mill. Three of the machines in the board mill are cylinder types with plain drier bearings and of these three, two are lubricated with a Lincoln Centromatic oil system, and the third machine is brick-grease lubricated. The remaining machine in the board mill is a fourdrinier type with antifriction drier bearings lubricated by means of a Bowser circulating oil system.

J. A. Box, Lubrication Engineer, Crown Zellerbach Corp., Bogalusa Division, Bogalusa, La.

In the sulfate mill, all three of the machines are fourdriniers. One machine is equipped with babbitt drier bearings and a Bowser circulating oil system, one with brass bushing drier bearings lubricated by means of a Lincoln Centromatic system, and the third with antifriction drier bearings lubricated with a Bowser system.

The wood yard, wood chipping and screening, digesters, evaporators, washing and screening make up another area of the mill, while still another is composed of the recovery boilers, lime kilns, slakers, and associated equipment. The bleach plant is still another separate area, as is the by-products department which includes the asphalt laminating machine, color machine, and reverse roll coater.

This, then, is the entire mill. Figure 2 shows the engineering department organization. Of interest here is the point that the lubrication engineer's position is one of staff rather than line. He reports to the assistant plant engineer and has no men directly under him. The mechanical department

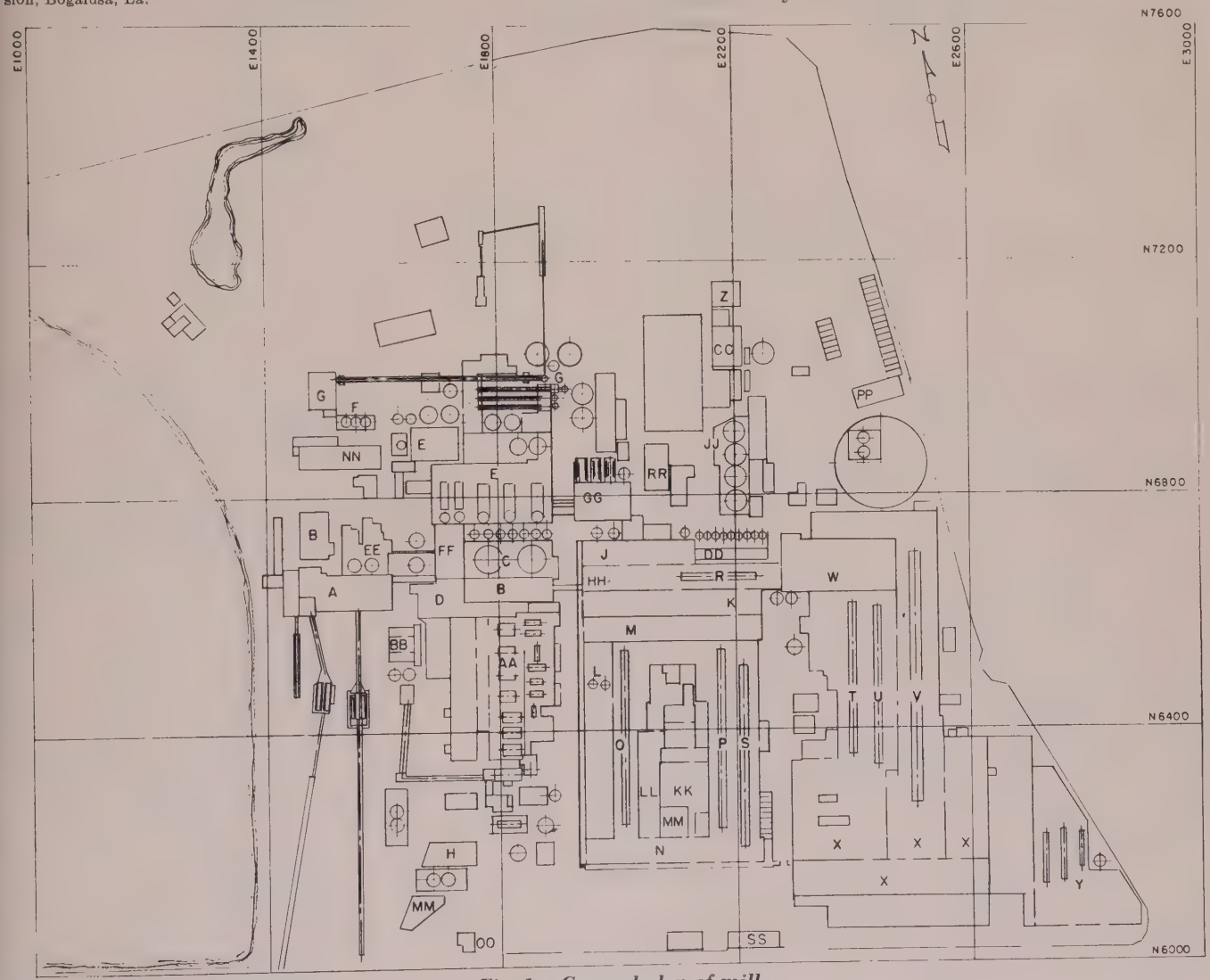

Fig. 1. General plan of mill

A	Wood Room	M	Fidalgo Building	W	No. 5 Machine	EE_9	Pipe Shop
B	Digester Room	N	Attrition Mills	X	No. 6 Machine	JJ	Synthetic Liquor Plant
B_1	Digester Room	P	Waste Paper Beater	AA	Alum Plant	KK	By-Products Plant
C	Diffuser Room	Q	Board Mill Beater Room	BB	Power Plant	LL	No. 7 Machine
D	Evaporator Room	Q_1	Board Mill Finishing Room	BB_1	Power Plant Cooling Tower	BP	Bleach Plant
D_1	Evaporating Cooling Tower	R	No. 1 Machine	CC	Electrical Substations	BT	Blow Tank Building
E	Recovery Room	S	No. 2 Machine	EE_1	Time Office	CA	Brown Stock Washers (Swensons)
F	Causticizing Department	T	No. 3 Machine	EE_2	Machine Shop	CB	Impco Washers
G	Lime Recovery	U	No. 4 Machine	EE_3	Electrical Shop	CD	Continuous Digesters
H	CLO_2 Refrigeration Plant	V	Sulfate Beater Room	EE_4	Supply Room	EB	Engineering Building
H_1	CLO_2 Generator	V	Sulfate Finishing Room	EE_5	Meter Shop	SS	Stock Storage
K	Turpentine Refinery	V	Asphalt Machine	EE_6	Garage		
L	Wet Room	V_1	Sulfate Mill Cooling Tower	EE_7	Belt Shop		
				EE_8	Carpenter Shop		

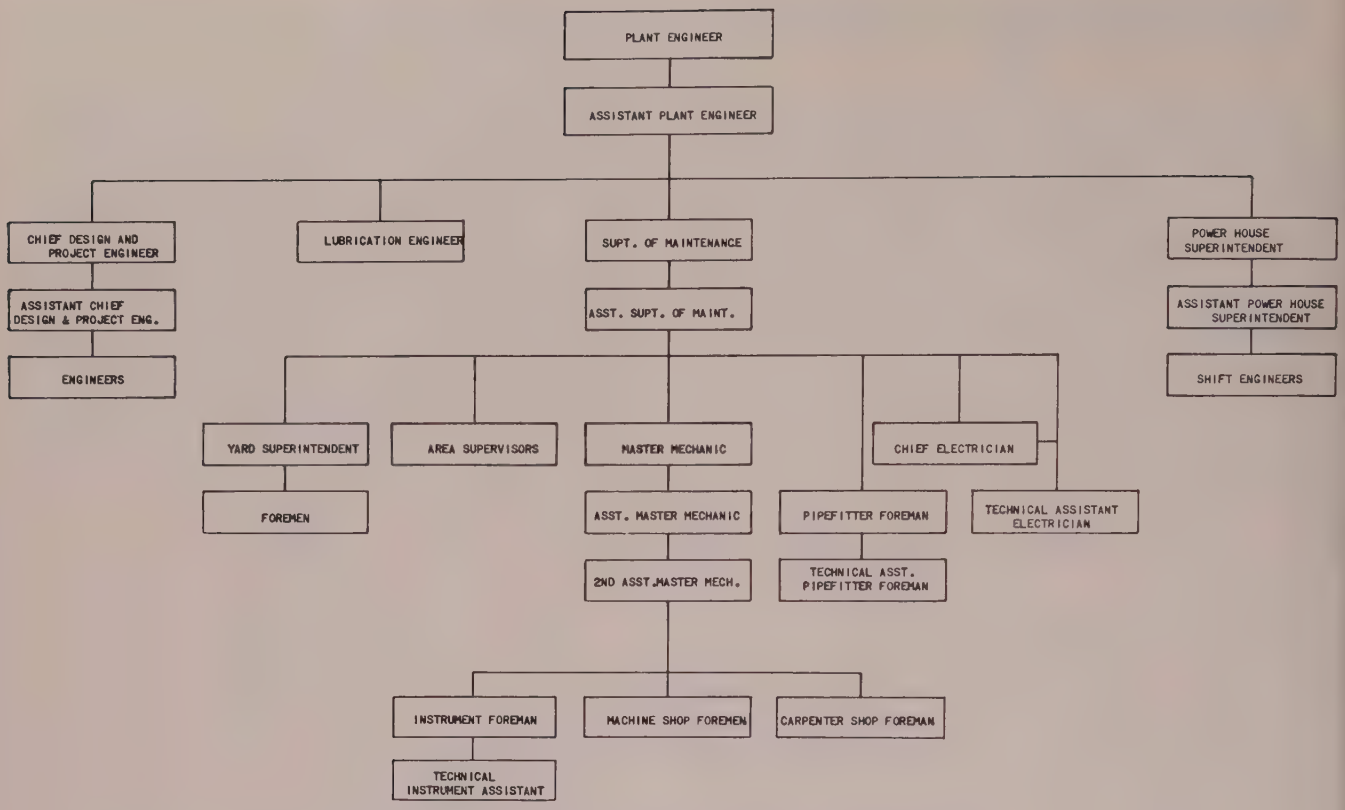

Fig. 2 Organization chart of engineering department

has several branches reporting to the superintendent of maintenance. However, the one of importance as far as the scope of this paper is concerned is that of the area supervisors. These men are in charge of operating maintenance personnel which includes millwrights and oilers (Fig. 3). From this standpoint the mill is divided into three areas, namely, the pulp mill, board mill, and sulfate mill with an area supervisor in each location.

As you will note there is a total of 29 oilers used throughout the plant on all the shifts. And as previously stated, these men report directly to the area mechanical supervisor in their respective departments. There is some overlapping of duties between the area supervisors and the lubrication engineer with respect to personnel and equipment. However, in our plant the lubrication engineer is used chiefly to initiate and supervise the lubrication program on a plant-wide basis. He collaborates with the area supervisor and with lubrication personnel to see that the lubrication program is being carried out effectively. On special occasions, such as shutdowns, he assists the area supervisors by directly supervising the work of the lubrication personnel. This frees the supervisor of this responsibility and gives him more time to devote to other necessary mechanical work. Although it may appear that this overlapping of supervision could cause some friction, in our case this has not proved to be so and the plan has worked quite smoothly.

The area supervisor and lubrication engineer collaborate on work schedules for the oilers during plant or departmental shutdowns. During this time work is performed that gener-

DISTRIBUTION OF OILERS

PULP MILL AREA SUPERVISOR	
WOOD MILL	- 4 OILERS
RECOVERY DEPARTMENT	4 "
BOARD MILL AREA SUPERVISOR	
NO. 1 & 3 MACHINES	- 4 OILERS
NO. 2 & 4 "	- 4 "
BLEACH PLANT	1 OILER
SULPHATE MILL AREA SUPERVISOR	
NO. 5 & 6 MACHINES	- 4 OILERS
NO. 7 MACHINE	- 4 "
BY-PRODUCTS DEPARTMENT	
ASPHALT LAMINATING MACHINE	- 4 OILERS
TOTAL - 29	"

Fig. 3. Distribution of oilers

OILER'S WORK LIST, NO. 5 & NO. 6 MACHINES

DECEMBER 26, 27, 28 & 29

1. CHANGE FILTER BAGS, #5 MACHINE OIL SYSTEM.
2. RENEW ALL OIL WICKS, FRONT AND BACK SIDE, #6 MACHINE.
3. CHANGE OIL IN DRIER SECTION GEAR DRIVES, #6 MACHINE.
4. CHANGE OIL IN WIRE COUCH DRIVE, #6 MACHINE.
5. DRAIN AND REFILL BELOIT DRIER BEARINGS, #6 MACHINE.
6. GREASE LINESHAFT BEARINGS, #6 MACHINE.
7. GREASE CLUTCHES, #6 MACHINE.
8. GREASE AND OIL COUPLINGS, #5 AND #6 MACHINES.
9. GREASE AND OIL FELT CONDITIONERS, #5 AND #6 MACHINES.
10. CLEAN BOTTOM CALENDER ROLL BEARING, #6.
11. GREASE AND OIL REWINDERS, #5 AND #6 MACHINES.
12. GREASE AND OIL ROPE SHEAVES, #5 AND #6 MACHINES.
13. GREASE AND OIL INTERLOCK SYSTEM, #5 MACHINE.
14. GREASE AND OIL CRANES, #5 AND #6 MACHINES.
15. GREASE AND OIL NEW PARTS INSTALLED ON THIS SHUTDOWN.

JABJR/JAS
12/16/58

Fig. 4. Typical work list

ally cannot be done at any other time (Fig. 4). This includes such work as oil changes in large gear drives, lubrication of conveyor rolls, and maintenance on the large Bowser oil reservoirs. The items on the work list are checked off when they are completed and at the conclusion of the entire job the list is turned in to the lubrication engineer for filing.

In addition to the departmental shutdown work lists, the oiler's work is scheduled for his regular or routine jobs. Drawings of these operations will show that in some locations the scheduling is by specific areas rather than by individual pieces of equipment. This is done in an effort to keep the schedule as simple and straightforward as possible and thus to eliminate the necessity for the oiler to read a lengthy book in order to determine his work for the day. Figure 5 shows a typical work list based primarily upon the listing of specific equipment. As will be noted the major portion of the equipment to be oiled is scheduled for the morning shift, whereas the work on the afternoon shift is devoted to equipment to be greased. Figure 6 shows a typical work schedule based primarily on areas. Here, too, the oiling is done on the morning shift and the greasing is done on the afternoon shift. The oiler on the midnight shift in both areas is used for routine oiling and inspection.

The lubrication needs of the plant originally were determined by a survey which was made jointly by a lubrication engineer from our lubricant supplier and by the plant lubrication engineer. Necessarily, this survey is quite lengthy and is changed periodically as new equipment is added and old equipment removed. It was made to minimize the number of lubricants used, to standardize the lubricants used by departments, and to obtain an accurate picture of the lubrication practices which existed at the time. Upon completion of the survey, lubrication charts were prepared for posting in the various oil houses throughout the plant. These charts showed the oilers what lubricants should be used in his equipment. In some instances the charts are an integral part of his work schedule while in others it is separate. The issuance of the charts and the work schedules does not necessarily guarantee that they will be followed, so periodic checks are made by the lubrication engineer and area supervisor to see that this is being done. This is particularly true in seeing that he follows without variation the chart for choice of lubricants. When new lubricants are evaluated and are chosen to replace older types, the change is not made without first explaining to the oiler why it is being done. It is felt that this helps to improve his morale and make him realize that his job is one of importance.

Fortunately, our oil supplier is located near the mill which eliminates the necessity of our keeping a large number of drums of oil in storage. In an emergency a drum of oil can be delivered from the bulk plant in less than a half hour. However, there is a central oil house which is operated by our purchasing and supply department. At this oil house there are located four 4000/gal. storage tanks. To obtain the best possible price, the oils which are used in large quantities are bought in compartmented tank-car lots and stored here. Daily requisitions for oil are filled by the supply department by two means, (1) by filling drums from the storage tanks, or

WORK SCHEDULE FOR WOOD ROOM OILERS

MORNING SHIFT:

Check and add oil as needed in the following:

Saturday: (1) Air compressors (one at Wood Room, one at New Brown Stock Washer Room, one at Continuous Digester).
(2) Fill drip cup on rechipper shaker screen.
(3) All equipment in new Washer Room.
(4) Flat screens, deknotters and Oliver's at Wet Room.
(5) Fill drip cups on old Brown Stock Washers.
(6) Pump bearings under #3 Diffuser Room.
(7) Elevator chain to new chip storage room.
(8) Grease rechipper bearings.
(9) Grease barking drums from 2 to 3 P.M.
(10) Grease deknotter bearings at new Washer Room.
(11) Lindblad Screen Bearings.
(12) Bauer Refiners.
(13) Claflin Refiners.
(14) Pressafiner Gear Drives.
(15) Discharge Valve Oil System.
(16) Pumps at Continuous Digester.
(17) Screw Feeder Bearings.
(18) Vacuum pumps under Brown Stock Washers.
(19) Pumps under #2 Diffuser Room.
(20) Reduction gears on Malone Filters.

Sunday: (1) Same as above
(19)
(20) Reduction gears in Wet Room cellar.
(21) Chain drives on #1 and #2 Diffuser Stock Chests.
(22) Trunnion bearings on old Brown Stock Washers.

Monday: (1) Same as above
(17)
(18) Chain and reduction gears at both chip bins.
(19) Reduction gears under Brown Stock Blow Tanks.
(20) Reduction gears on Malone Filters.

Tuesday: (1) Same as above
(17)
(18) Drip pans, bearings and reduction gear, #4 Barking Drum.
(19) Reduction gears and chains under #1, 2, 3 & 4 Barking Drums.
(20) Oil level in tank for hydraulic valves at new Digester Room.

Wednesday: (1) Same as above
(17)
(18) Reduction gears and chains at Saw Mill.
(19) Wood bucket and reduction gears on P&H.
(20) Reduction gears on chains, #1 and 2 Barking Drums.
(21) Pour gear grease on all open gear drives.

Thursday: (1) Same as above
(17)
(18) Reduction gears on #1, 2, 3 & 4 Barking Drums.
(19) Guide roll bearing, #3 Barking Drum.
(20) Reduction gear and chain over and under #3 Chipper.
(21) Reduction gear and chain to #3, 4 & 5 Shaker Screens.
(22) Reduction gears on Malone Filters.
(23) Trunnion bearings on old Brown Stock Washers.

Friday: (1) Same as above
(17)
(18) Reduction gear on #3 Shaker Screen.
(19) Chains on Stock Chest agitator, #1 and 2 Diffusers.
(20) Drip cup on #3 Diffuser.
(21) Reduction gear and chains at stock storage.
(22) Reduction gear and chains in wood room cellar.

AFTERNOON SHIFT:

Grease equipment as follows:

Thursday: (1) #1, 2, 3, & 4 Shaker Screens while knives are being changed on chippers.
(2) Wood chains and chain drives.
(3) Sawdust belt drive on new and old barking drums.
(4) Equipment in Wood Room Cellar.
(5) Conveyors at Continuous Digesters.
(6) Check air compressors.
(7) Fill drip cup on rechipper shaker screen.

Friday: (1) Brown Stock Washer pumps (under new Diffuser Room).
(2) Equipment at New Chip Bin.
(3) Equipment at Old Chip Bin.
(4) Same as (6) above.
(5) Same as (7) above.

Saturday: (1) All pumps in Evaporator Room.
(2) Pumps under #2 Diffuser Room.
(3) Same as (6) on Thursday.
(4) Same as (7) on Thursday.

Sunday: (1) Equipment at Wet Room – upstairs, main floor and cellar.
(2) Save-all pumps.
(3) Same as (6) on Thursday.
(4) Same as (7) on Thursday.

Monday: (1) All equipment at old Washers and #2 Diffuser Room.
(2) Saw Mill Equipment.
(3) Same as (6) Thursday.
(4) Same as (7) Thursday.

Tuesday: (1) Same as (1) on Thursday
(2) Same as (1) on Friday
(3) Same as (6) on Thursday
(4) Same as (7) on Thursday

Wednesday: (1) New Washer Room Equipment and ImpCo Screens – Upstairs and down.
(2) Equipment at No. 3 Diffuser Room.
(3) Same as (6) on Thursday.
(4) Same as (7) on Thursday.

MIDNIGHT SHIFT:

Routine oiling as follows:

Tuesday: (1) Check air compressors
(2) Fill drip cup on rechipper shaker screen.
(3) Equipment at Wet Room.
(4) Equipment downstairs at #2 and #3 Diffuser Rooms.
(5) Oil sprays on chains at Wood Room.
(6) Check oil level on bearings on new washers and Lindblad Screens.

Wednesday: (1) Same as above
(6)

Thursday: (1) Same as above
(6)

Friday: (1) Same as above
(6)

Saturday: (1) Same as above
(6)

Sunday: (1) Same as above
(6)

Monday: (1) Same as above
(6)

– LUBRICANTS TO USE –

AIR COMPRESSORS	–	HARMONY 53
WASHER GEAR DRIVES AND BEARINGS	–	SENATE 158F
CHIPPER BEARINGS	–	SENATE 158F
LINDBLAD SCREENS	–	HARMONY 61
PRESSAFINERS	–	DIESELUBE HD50
BAUER & CLAFLIN REFINERS	–	HARMONY 69
WORM GEAR DRIVES	–	SENATE 158F
OTHER REDUCTION GEARS	–	SENECA 75
ROUTINE OILING	–	SENECA 75
OPEN GEARS	–	LUBCOTE #3

Fig. 5. Work schedule for wood room oilers

WORK SCHEDULE FOR LIME KILN OILERS

MORNING SHIFT:

Check and add oil as needed in the following:

Saturday:	(1)	Air compressors, crankcase and lubricator.
	(2)	Slaker, hot chains, mud filters.
	(3)	No. 4 Lime Kiln Fan.
	(4)	All equipment in Recovery Room.
Sunday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	All equipment on ground floor of Lime Kiln.
Monday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Airveyors
	(5)	Lime elevators (2)
	(6)	Vibrators on precipitators
Tuesday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	All equipment above ground floor of Lime Kiln.
Wednesday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Vibrators on precipitators
	(5)	Equipment on top of salt cake tanks
Thursday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Salt Cake Feeders
	(5)	Salt Cake Mixing Tank
	(6)	Salt Cake Elevators
Friday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Vibrators on precipitators
	(5)	Clarifiers (2) in Lime Kiln

AFTERNOON SHIFT:

Check oil and add as needed in the first three items and grease the others:

Thursday:	(1)	Air compressors, crankcase and lubricator.
	(2)	Slaker, hot chains, mud filters.
	(3)	No. 4 Lime Kiln Fan.
	(4)	Equipment on ground floor of Recovery Room.
Friday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Equipment on floors above ground of Rec. Rm.
Saturday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Salt cake tanks - upstairs and down
Sunday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Hot chain and equipment at end of No. 4 Kiln.
Monday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Spray pumps in Recovery Room.
	(5)	Equipment on ground floor of Lime Kiln.
Tuesday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Equipment at Filter House.
Wednesday:	(1)	
	(2)	Same as Items 1, 2, 3 above
	(3)	
	(4)	Clarifiers
	(5)	Wash Tanks
	(6)	Airveyors
	(7)	Rock Conveyor

MIDNIGHT SHIFT:

Check, add oil and grease in following equipment as needed:

Tuesday:	(1)	Air compressors, crankcase and lubricators.
	(2)	Slaker, hot chains, mud filters.
	(3)	No. 4 Lime Kiln Fan.
	(4)	Pack bearings on 1, 2 & 3 Lime Kilns.
	(5)	Vacuum Pumps.
Wednesday:	(1)	
	(2)	
	(3)	Same as above
	(4)	
	(5)	
Thursday:	(1)	
	(2)	
	(3)	Same as above
	(4)	
	(5)	
Friday:	(1)	
	(2)	
	(3)	Same as above
	(4)	
	(5)	
Saturday:	(1)	
	(2)	
	(3)	Same as above
	(4)	
	(5)	
Sunday:	(1)	
	(2)	
	(3)	Same as above
	(4)	
	(5)	
Monday:	(1)	
	(2)	
	(3)	Same as above
	(4)	
	(5)	

Fig. 6. Work schedule for lime kiln oilers

(2) by ordering from the bulk plant those oils which are not kept at the central oil house. Greases are generally bought by the purchasing department in 400-lb. drums. As requisitions are filled the grease is transferred into 120-lb. drums for delivery to the plant. The services of two supply department men are required about 2 hours per day, with the exception of Saturday and Sunday, in filling the oil, grease and kerosene orders. Oil and grease deliveries are made once each week day to the oil houses located in each of the areas previously mentioned. The requisitions are originated generally by area supervisors, assistant area supervisors, or the lubrication engineer. However, they can be signed by any of the other foremen (Fig. 7).

Brand names are used on the requisitions and drums as delivered to the area oil houses. The supply department records the serequisitions daily on an Oil & Grease Report form (Fig. 8). In this manner the charge for the material is made against the proper department. At the end of the month a tabulation is made of the charges and the resulting figures are compiled and distributed in a Lubricant Report. As shown in Fig. 9 this report shows the cost per department and cost per ton of production.

In addition, still another cost report is made up by breaking down the departmental charges even further and comparing these results with the charges of 1 year ago and 5 years ago (Fig. 10).

Thus from the three reports it is quite easy to ascertain daily, weekly, or monthly the type of lubricant purchased, the amount used, and the cost. Lubricant waste or the purchase of the wrong type of lubricant can also be detected from these reports and efficient control can be maintained by use of them.

STOCK REQUISITION

ACCT. NO. 804-41-0 EX. NO. ____ DATE APRIL 29 1959

G. B. NO. ____ W. O. NO. ____

QUANTITY	DESCRIPTION	STOCK NUMBER	PRICE
3	Drums Paper Machine Oil X-3307		141 90

ORIGINATED BY R. R. Nichols

RECEIVED BY ____ ISSUED BY H. J. ____ TOTAL 141.90

FLASH PRINTERS

Fig. 7. Typical requisition

Some of the equipment in our plant is of old design which had poor provisions for lubrication. One of the most rewarding fields for a lubrication engineer is in improving the method of lubricant application on machines such as these. In our case this has been done with a gratifying reduction in the number of bearing and gear losses in some instances.

For example, machine no. 1 is an old cylinder machine with open gears and plain drier bearings. Previous to the installation of the Centromatic system the back bearings were hand-oiled when the machine was down for a felt change. They could not be re-lubricated until the machine went down again; this period might be as long as 20 days. This feast-and-famine lubrication led to many drier bearing and gear losses. For the period November, 1952, to November, 1956, when the central system was put into service, there was an average of 90 replacements per year (Fig. 11); at a cost of $40.39 per bearing brass the yearly cost was $3635.10. In addition, there was an average of 7.5 gear replacements per year at a cost of $335 per gear for a yearly cost of $2512.50, and a total cost of $6147.60 excluding installation costs or possible production losses. There has been an average of 5.5 bearing and 1.4 gear replacements per year since 1956 for an average cost per year of $933.38. This represents a saving in parts cost alone of $5214.12 annually.

GAYLORD CONTAINER CORPORATION

MILL DIVISION

Account No. 804-41 OIL AND GREASE REPORT NO. 4 MACHINE

Date	X-3307	Daily Cost
4-2	1	39 60
4-6	1	24 00
4-7	3	141 90
4-29	3	127 20
TOTAL		$ 332 70

Fig. 8. Oil and Grease Report

GAYLORD CONTAINER CORPORATION
DIVISION OF CROWN ZELLERBACH CORPORATION
MILL DIVISION
BOGALUSA, LOUISIANA

MR. H. J. FOIL

LUBRICATION REPORT FOR THE MONTH OF MAY 1959.

DEPARTMENT	TONNAGE	AMOUNT	COST PER TON
SULPHATE PULP MILL	30713	$ 1315.95	.0428
NO. 1 MACHINE	4222	541.30	.1282
NO. 2 MACHINE	2346	72.20	.0307
NO. 3 MACHINE	1144	56.30	.0492
NO. 4 MACHINE	5216	362.90	.0696
NO. 5 MACHINE	2547	378.64	.1486
NO. 6 MACHINE	3164	624.05	.1972
NO. 7 MACHINE	11908	455.30	.0305
LAMINATING MACHINE	724	43.20	.0596
POWER HOUSE	61984	125.95	.0019
MISCELLANEOUS	61984	783.78	.0120
TOTAL	61984	$4,759.57	0732

Fig. 9. Monthly lubrication report

In another instance our asphalt laminating machine was originally equipped with plain bearings which were inadequately sealed. Hot asphalt entered the bearing, plugged up the oil grooves and drains, and forced out the oil. The brass bearings were replaced on an average of once per month and this was a time-consuming job, for the machine had to be practically dismantled to remove the bottom rolls to get to the bearings. In addition to excessive maintenance cost, the oil costs ran as high as $800 per month. After the housings were redesigned for the installation of antifriction bearings and adequate seals, the oil cost decreased to $50 per month and the repair shutdowns are now scheduled annually. This improvement was done at a cost of $1759.

The antifriction drier bearings on our paper machines so equipped are inspected annually and it is felt that this preventive maintenance has resulted in worthwhile savings. The lubrication engineer maintains a permanent record of drier bearing inspections and changes made. These reports show at a glance the changes which have been made and indicate trouble spots when they exist. Fig. 12 is an illustration of a typical page of this report.

An important adjunct to the life of a bearing is, of course, the condition of the oil used on it. In the Bowser circulating system a sample is periodically removed for complete examination by our oil supplier. Less complicated oil analyses, such as acid number, viscosity, and water are made in our laboratory on samples from other smaller systems throughout the mill. These include turbine oils, diesel engine crankcase oils, and certain gear-case oils. In addition, film strength tests are run on some of the extreme pressure oils. Examination of results of these tests and comparison with the characteristics of similar new oil determine whether continued use is indicated or whether reconditioning or replacement is necessary.

LUBRICANT COST REPORT
MAY, 1959

To: B.B. PIERCE

DEP'T.	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVG. LAST YEAR	AVG. 5 YRS. AGO
WOOD MILL	$239.60	$ 161.00	$278.82	$164.20	$296.20								$336.80	$251.20
SEMI-CHEM.	--	--	--	--	--								--	--
CONTINUOUS COOKER	46.70	45.09	--	89.75	75.35								--	--
RECOVERY ROOM	206.50	200.14	39.60	161.55	118.90								178.70	176.70
EVAP & SLAKER	121.30	14.40	--	--	28.80								26.40	26.40
WASHERS & SCRS.	239.00	379.55	180.90	286.85	49.70								17.60	17.60
LIME KILN	101.50	17.55	182.00	216.40	305.40								80.60	17.70
ATTRITION MILL	118.80	39.60	79.20	79.20	39.60								--	--
WASTE PAPER	--	--	19.04	--	58.40								100.10	100.10
NO. 1 MACH.	306.50	316.10	392.60	421.90	492.90								347.60	347.60
NO 2 MACH.	152.90	300.90	262.70	501.20	72.20								70.00	70.00
NO. 3 MACH	137.60	62.60	120.80	38.60	56.30								280.80	280.80
NO 4 MACH	134.70	442.80	205.70	332.70	362.90								277.77	277.77
NO 5 MACH.	412.50	170.84	392.60	527.00	578.64								348.00	348.00
NO 6 MACH.	602.88	651.70	534.65	752.60	624.05								1,972.00	1,972.00
NO 7 MACH.	237.20	607.90	663.60	470.61	455.30								305.00	305.00
LAMINATING MACHINE	76.10	65.20	65.65	103.60	43.20								59.60	59.60
POWER HOUSE	225.30	96.80	182.60	241.95	125.95								254.40	254.40
GARAGE & YARD	370.29	563.80	666.12	595.57	662.05								--	--
TRAIN & CAR SHOP	169.60	86.20	119.20	337.25	321.75								29.40	29.40
BLEACH PLANT	--	--	--	27.50	--								17.75	17.75
GEN'L PLANT	--	--	--	--	--								174.70	174.70
TOTAL	$3,690.57	$3,865.54	$4,695.54	$6861.43	$4759.57								$6,440.00	$6,291.70

REMARKS: 5 DRUMS MAKE-UP OIL ADDED TO NO. 1 MACHINE
8 DRUMS MAKE-UP OIL ADDED TO NO. 7 MACHINE

Fig. 10. Lubricant cost report

NO. 1 MACHINE BEARING AND GEAR COSTS

COST FOR PERIOD NOVEMBER, 1952 TO NOVEMBER, 1956

360 BEARING BRASSES at $ 40.39 = $14,540.40
30 DRIER GEARS at 335.00 = 10,050.00
TOTAL $24,590.40

$24,590.40 ÷ 4 YEARS = $6,147.50 YEARLY COST

COST FOR PERIOD NOVEMBER, 1956 TO JULY, 1959

20 BEARING BRASSES at $ 40.39 = $ 807.80
5 DRIER GEARS at 335.00 = 1,675.00
TOTAL $2,482.80

$2,482.80 ÷ 2.66 YEARS = $933.38 YEARLY COST

$6,147.50 − 933.38 = $5,214.12 SAVINGS PER YEAR

Fig. 11. No. 1 machine bearing and gear costs

Not the least important in a lubrication program is the training of the men to whom the work is actually entrusted. The line of promotion in our mechanical department is: millwright helper, to oiler, to millwright. In this manner the man has gained considerably mechanical knowledge before he becomes an oiler. However, the training he receives before becoming an oiler is gained chiefly by on-the-job training under the guidance of an experienced man. Since we do not have a training department in our plant this is perhaps the best means of preparing the man for this job. In addition, the lubrication engineer is available to individual oilers to answer questions that may arise and explain any changes to be made.

BEARING CHANGES
NO. 7 MACHINE
BACK SIDE PAPER DRIERS
C - Indicates Changed
T - " Turned

DATE	FEB. 1948	DEC. 1948	MAR. 1949	DEC. 1949	MAR. 1950	JAN. 1951	JULY 1951	JAN. 1952	MAR. 1953	APR. 1954	DEC. 1954	SEPT. 1955	JUNE 1956	APR. 1957	DEC. 1958
Drier No. 42					T										
43							T								
44						C									
45				C										T	
46				T											
47															
48															
49	T														
50															
51	C														
52															
53														C	
54															
55															
56															
57															
58						C									
59												C			
60										C					
61													C		
62												C			
63													C		
64															
65															
66									T						
67															C
68									T						
69														T	
70															
71															
72															

Fig. 12. Chart of bearing changes, no. 7 machine

In brief, a good lubrication program depends upon good housekeeping, the provision of good lubricants, adequate work schedules, and supervision to see that the work is accomplished as planned.

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11th Testing Conference
Sponsored by
TAPPI
Pantlind Hotel
Grand Rapids, Mich.
Sept. 27–29, 1960

Microparticle Size Vinyl Acetate Copolymer Emulsions as Economical Low Odor Clay Coating Binders

NORMAN G. TOMPKINS

VINYL acetate polymer and internally plasticized copolymer emulsions have probably been suggested and tried as paper coating binders for as long as they have been available commercially, and possibly before. The reason is seen in some of their characteristic properties which fit remarkably well with the many and complex requirements which a latex for this use is required to meet. The strong tendency of polyvinyl acetate type materials to adhere to a great variety of surfaces including especially cellulosic materials such as wood and paper products is well known. It has been applied extensively in wood glues and packaging adhesives as well as in certain types of paint. Typical vinyl acetate resins are water white in color and remarkably color stable. They would thus not detract from brightness of the coated sheet in either fresh or aged coated stock. The basic pigment binding ability of these emulsions as well as their water resistance is demonstrated by their wide use in exterior and interior paints. Their low odor characteristics have been recognized and applied for many years. We find the homopolymers used in chewing gum and in many specialty greaseproof coatings used in food packaging. Their flexibility and degree of hardness can easily be varied; in the homopolymers, by the use of plasticizers, and in the copolymers, by the nature and amount of comonomer. With copolymer emulsions particularly, degree of hardness is constant with time and there is no tendency for films to become brittle. Also, all of these resins are saturated in the chemical sense and do not harden and embrittle through oxidation or oxygen catalyzed polymerization. The emulsions are stable mechanically and well suited to use in high speed coating equipment where the colors are often subjected to very high rates of shear. They do not have excessive foaming tendencies which would be a disadvantage in much papercoating work. Their effect on other papercoating properties, ease of calendering. ink receptivity, gloss ink holdout, drying speed, etc., is harder to predict but there seems to be little reason to believe they would behave unsatisfactorily in these respects. In addition, there is the fact that polyvinyl acetate and vinyl acetate copolymers are economical, low cost materials in the same price range as the butadiene-styrene latices so widely used today in this application and considerably less costly than the acrylic ester latices which are used extensively in coatings for food packaging stocks.

Yet, at the present time, when very large amounts of polymer dispersions are being used in paper coating, and while the trend is toward the use of still greater quantities, very, very little vinyl acetate polymer or copolymer is used in this way. The reason for this seems to be, not in the inherent properties of the resin which are nearly ideal for the purpose, but in the fact that the forms in which these resins have so far been available have been ill suited to this application. One of the main factors has certainly been particle size of the dispersions. The butadiene-styrene and polyacrylic ester dispersions which are presently used extensively in papercoating have particles in the one-tenth micron range. Most of the polyvinyl acetate materials available until recently have been manufactured using a protective colloid type emulsifying system giving a minimum particle size of around 0.5 μ ranging up to as much as 5μ. Since particle size is one of the most important factors in determining the pigment binding power of a latex, it is not surprising to find that most attempts to use these emulsions in paper coatings resulted either in inferior coatings having poor pick resistance or in higher cost because of the greater quantities of binder necessary to give good printing quality. In addition to the cost. of course, increased binder ratios detract from brightness, opacity, and gloss.

NORMAN G. TOMPKINS, Research Department, Organic Chemicals Division, Dewey and Almy Chemical Division, W. R. Grace & Co., Cambridge, Mass.

Table I

	Pounds
Clay	75
Calcium carbonate	25
Tetrasodium pyrophosphate	0.2
25% Starch solution	46.8
Water	15.6
55% Vinyl acetate copolymer latex	11.4
	174.0

MICROPARTICLE SIZE EMULSIONS

Recent technical developments have, however, made available polyvinyl acetate and vinyl acetate copolymers in the form of emulsions having particles in 0.1- to 0.2-μ range. In these, seemingly, we have the excellent inherent properties of the vinyl acetate polymer or copolymer resin combined with the advantages of an emulsion in the same particle size range as the currently used butadiene-styrene or acrylate ester emulsions. Neither of the latter types of latex is ideal for papercoating. The acrylate ester emulsions give excellent performance but are undesirably high in cost. On the other hand, the butadiene-styrene latices have disadvantages with regard to odor, tendency to yellow and embrittle with age and a time lag which may amount to several weeks between coating and attainment of best printing properties. Therefore, it seems wise to consider vinyl acetate polymers and copolymers once more in the light of these new developments to determine to what extent previous objections have been overcome and whether the excellent characteristics of this class of resins can now be effectively applied in the papercoating field.

STARCH-LATEX BOUND COATINGS

During the summer of 1958 several coating runs were made using microparticle size, vinyl acetate copolymer latices in starch-latex bound coatings. The coatings were applied on 40 lb. basis weight stock using a print roll coater at speeds of 225 to 600 f.p.m. The basic formula for the colors used is given in Table I.

The binder level on this formula is 18 lb. per 100 lb. of pigment, the total solids content is 68% and latex solids comprises 35% of the total binder, probably a rather high proportion for printing paper stocks of this class but one designed to show up clearly differences between latices. The combination of clay and calcium carbonate was chosen as most representative of industry practice.

The color was made by stirring the pigments, tetrasodium

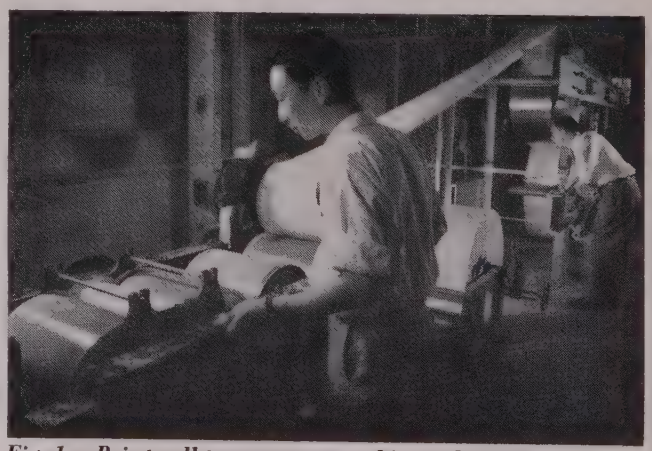

Fig. 1. Print roll type coater used in evaluation of starch-latex bound coatings

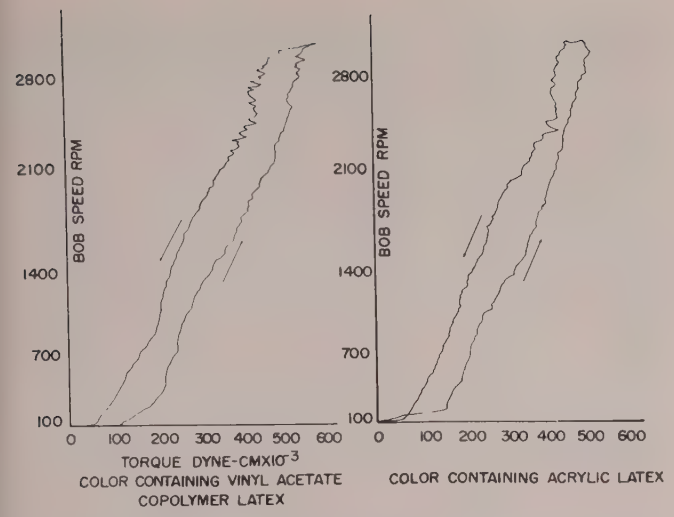

Fig. 2. Hercules rheograms showing similar rheological behavior of starch-acrylic and starch-vinyl acetate copolymer colors

pyrophosphate, and four fifths of the starch solution in a sigma-bladed mixer at high consistency and 80% total solids content for a period of 2 hr. At the end of this time the remaining starch solution, the water and the latex were added and stirring was continued for 30 min. at increased speed. The color was then ready for use.

Brookfield viscosities were very close to 250 cp. at 50 r.p.m. and 160 cp. at 100 r.p.m. Hercules rheograms obtained with vinyl acetate copolymer latices were very similar to those observed with the polyacrylate dispersions widely used in coatings of this type as shown in Fig. 2.

Some of the results obtained on supercalendered sheets in this work are shown in Table II.

These runs are not strictly comparable because of the heavy coating weight in run no. 3. But it is interesting to note the slightly higher brightnesses achieved in runs no. 1 and no. 2 in spite of the heavier coating on the paper from run no. 3. The vinyl acetate copolymer latex seemed to give adequate performance in the wet rub test and, although the IGT pick resistance test seems to show a deficiency in the vinyl acetate copolymer in the particular run considered here, results on other runs indicated that the difference was actually not so large as these data would seem to indicate.

In these initial experiments, complete success in equaling conventionally bound coatings was not achieved but nevertheless results were far better than had previously been thought possible with a polyvinyl acetate binder.

COATINGS WITH ALL-LATEX BINDER

Our attention was then called to an odor problem existing on certain types of bread and frozen food wrap which precluded in many cases the use of butadiene-styrene latices and made necessary one of the much more costly acrylic ester latices.

Table II

Latex	*Run 1 Vinyl acetate copolymer latex*	*Run 2 Acrylic ester*	*Run 3 Butadiene-styrene*
Coating weight lb./TAPPI ream	10.8	11.8	15.3
Sheffield smoothness (cc./sec./sq. in.) × 10	24.4	23.3	25.1
Hunter brightness, %	82.2	82.0	79.6
Ingersoll gloss, %	86.8	88.1	89.6
Opacity, %	91.2	91.0	93.3
IGT pick resistance, ft./min. (no. 2 ink)	240	324	332
Aminco wet rub (cycles to failure)			
Machine direction	10.4	11.0	8.8
Cross-machine	8.0	9.8	8.0

Table III

	Pounds
Clay (predispersed type)	50
Titanium dioxide	50
Casein solution, 23%[a]	2
Water	80.7
Vinyl acetate copolymer dispersion 55% nonvolatile	27.3
	210.0

[a] Cut with 4% NaOH calcd. on casein.

Since vinyl acetate copolymer latices are less expensive than acrylic ester products and do not involve the odor problems of most butadiene-styrene latices, it was decided to investigate the behavior of the new microparticle vinyl acetate copolymer latices in coatings of this kind.

Our original test was made on a trailing blade type coater using approximately 25 lb. basis weight stock with a dry coating weight of 2½ to 3 lb. per 25 x 38–500 in. sheet ream. The color formulation is shown in Table III.

Colors of this type were made using a Cowles dissolver. The clay, titanium dioxide, and water were first dispersed at 2000 r.p.m. for 15 min. after which the casein or polyvinyl alcohol solution and the latex were added and stirred in with an ordinary laboratory agitator. These colors were made up to 55% nonvolatile content.

Tests on this initial run in comparison with similar material made using a standard acrylate ester type latex showed that it was measurably deficient in pick resistance with respect to the acrylate-bound control when tested on the Vandercook proof press using no. 7 tack graded ink.

A series of hand-coated sheets were then made to determine if the pick resistance could be improved either by substituting a dispersion of a somewhat harder copolymer or by means of certain formula variations. These were made on 27 ½-lb. basis weight stock laid on plate glass and using a no. 5 Meyer bar or wire-wound rod. Coating weights obtained by this method with the undiluted color were in too high a range and it was necessary to dilute to 25% total solids content in order to get coating weights in the 4- to 5-lb. range. Although the coating weights were about twice what was desired on this series, the results of comparisons of the uncalendered sheets using the Vandercook proof press gave several interesting indications, as shown in Table IV.

The pick resistance comparisons made using the Vandercook proof press are quite reliable and reproducible but unfortunately only a comparison between papers can be made and no absolute values of the pick resistance of any one paper can be obtained. The figures in the table were obtained by visually rating the printed samples of paper, giving attention both to the appearance of the printed sheet and to any picking

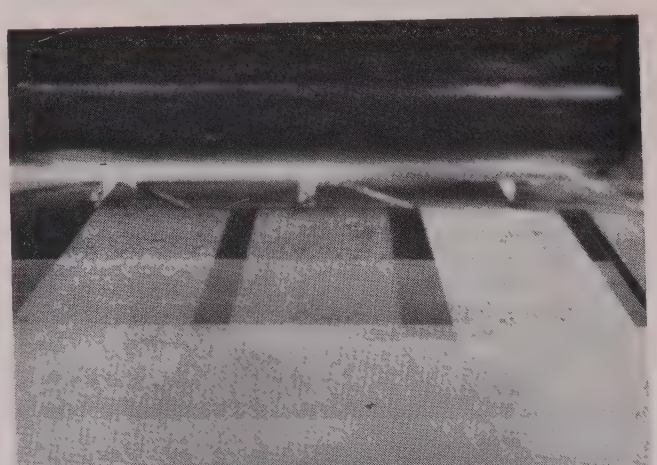

Fig. 3. Printing plate after making typical Vandercook test. Polyacrylate latex + 3% casein; vinyl acetate copolymer + 3½% low viscosity, partially hydrolyzed polyvinyl alcohol; vinyl acetate copolymer + 3% casein

Table IV. 100% Latex Bound Coatings Hand-Coated Sheets

Latex	Total binder lb. latex/100 lb. pigment	Latex solids in binder, %	Amt. of stabilizer or additive calcd. on latex solids, %	Vandercook results no. 6 ink	Vandercook results no. 7 ink
Acrylate ester latex	..	97	3 casein	10	9
Soft vinyl acetate copolymer emulsion	15	97	3½ PVAlcohol	10	10
"	15	97	3 casein	5	3
"	16	94	6 casein	7	5
"	18	84	12 casein	10	7
"	17.5	97	3 casein	10	7
"	18	75	33 starch	10	9
Harder vinyl acetate copolymer emulsion	15	97	3½ PVAlcohol	10	10
"	15	97	3 casein	7	7
"	15	94	6 casein	10	7
"	16	84	12 casein	10	7
"	17.5	97	3 casein	10	10

which showed on the printing plate (see Fig. 3). Rating was done using the ASTM scale from 10 (excellent) to 0 (complete failure).

Note that increasing amounts of casein gave improved results with both soft and harder vinyl acetate copolymer emulsions. The harder vinyl acetate copolymer emulsions proved to give better results than the soft copolymer emulsions in this series of 100%-bound coatings. Increases in total binder level were also helpful but by far the best results were obtained by substituting a small amount of partially hydrolyzed polyvinyl alcohol for the casein stabilizer. Three and one-half per cent of this material, as solids, calculated on the resin solids in the color was sufficient to bring the pick resistance as measured by Vandercook proof press comparisons up to equal results obtained using a standard polyacrylate latex.

A number of these tests were subsequently repeated in machine coating runs using a trailing blade type coater. The results of these runs are given in Table V, and confirm in a general way the bandsheet data, although there are some important differences.

It will be noted that in this series, the emulsion containing the softer of the two vinyl acetate copolymers gives the better results in terms of pick resistance except in the case where 12% of casein was added. In these tests an attempt was made to determine the relative pick resistance using the IGT pick tester. Results varied widely, however, and in individual tests on any given paper they did not seem to be entirely consistent or well correlated with the results obtained using the Vandercook proof press. For this reason, both a range and an average are given for each coated paper.

Apparently, with this particular type of coated and uncalendered sheet, it is far more difficult to obtain consistent and reproducible results with the IGT tester than with the Vandercook press even though the IGT machine gives a numerical result in feet per minute and the latter only a comparison which must be judged and rated subjectively. The figures in the last column were obtained in this case by rating at least four samples of each paper in the manner described for the hand-coated sheets and averaging the results, which were generally within one point of one another.

In making the hand-coated sheets as well as in carrying out the pilot machine coating runs it was observed that the colors containing the partially hydrolyzed polyvinyl alcohol seemed to flow and apply more uniformly and to have less tendency toward streaking than colors containing casein. This seemed to be true even when the principal binder was a polyacrylate ester emulsion. If this difference is borne out by further tests and in commercial scale use, it will be another cogent reason for serious consideration of these microparticle copolymer dispersions modified with polyvinyl alcohol, as binders for pigmented paper coatings of all kinds.

Table V. 100% Latex Bound Coatings Trailing Blade Coated Sheets

Latex	Total binder lb. latex/100 lb pigment	Amt. of stabilizer or additive calcd. on latex solids, %	Coating wt. lb./TAPPI ream	IGT Pick resistance, ft./min. no. 2 ink Range	IGT Pick resistance, ft./min. no. 2 ink Av.	Vandercook rating no. 7 ink
Acrylic ester latex	15	3 casein	3.2	...	..	7.5
Soft vinyl acetate copolymer dispersion	15	3½ PVAlcohol	2.2	280–525	361	7.3
"	15	2 PVAlcohol	2.7	...	..	6.0
"	15	3 casein	3.2	...	..	4.6
"	18	12 casein	3.2	240–425	320	5.6
"	17½	3 casein	3.4	330–445	390	5.8
Harder vinyl acetate copolymer dispersion	15	3½ PVAlcohol	3.1	140–250	183	4.8
"	15	3 casein	3.6	135–218	169	3.3
"	18	12 casein	3.2	240–475	320	5.6
"	17½	3 casein	2.9	130–220	200	5.5

DISCUSSION

Results so far have demonstrated that for pick resistance, a microparticle size, vinyl acetate copolymer emulsion modified with 3½% partially hydrolyzed polyvinyl alcohol will give results, on at least one type of coated stock, which are essentially equivalent to those obtained with commonly used acrylic ester latices. This point is illustrated in Fig. 4. There remains the effect of the substitution on other properties and the economic considerations.

With regard to the former, very fragmentary results have so far indicated that these coatings tend to have greater ink receptivity and slightly greater sensitivity to water than coatings bound with conventional latices. Both of these problems, however, if they prove to be critical can be attacked in several ways. The use of other, less soluble, grades of polyvinyl alcohol or the inclusion in the color of some ingredient which would tend to render it insoluble suggest themselves at once as means of obtaining greater water resistance.

As to economics, it is interesting to look at the costs per pound of the binders used in an acrylate-bound coating, and in the same coating in which the suggested blend of polyvinyl alcohol and vinyl acetate copolymer emulsion has been substituted for it. These are shown in Table VI.

Table VI. Binder Cost in Cents per Solid Pound

	Vinyl acetate copolymer	Acrylic ester
Latex	35.4	42.4
Casein at 21¢/lb.	..	0.6
Polyvinyl alcohol at 94¢/lb.	3.3	..
Total cost/lb. solid binder	38.7	43.0

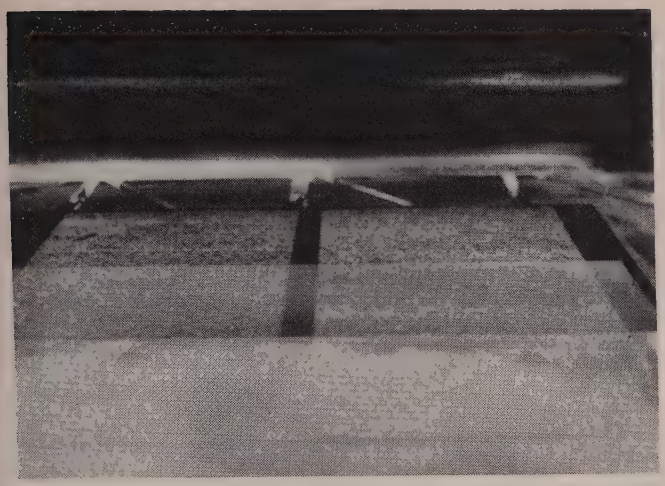

Fig. 4. Coating bound with acrylic latex + 3% casein; coating bound with vinyl acetate copolymer latex + 3½% polyvinyl alcohol

The savings realized by substituting the suggested blend would amount to 4.3¢ per lb. of solid binder, or 10% of the original binder cost, a very worth while economy for medium and large scale users of latex coating binders.

It is our belief that the results of this investigation, admittedly limited, are nevertheless definitely encouraging, and that the investigation of vinyl acetate polymer and copolymer emulsions of the microparticle size type as paper-coating binders ought to continue on an expanding scale. The work described here is being continued and extended and will, we feel, be supplemented by the efforts of a number of firms who do commercial papercoating and are anxious to explore all likely possibilities in their attempts to reduce their binder costs without affecting odor or printing quality.

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Application of a Urea-Formaldehyde Concentrate to Starch-Clay Coatings on a High Solids Pilot Plant Roll Coater

G. K. CLEEK and R. C. CHASE

The results of previous work on the use of a urea-formaldehyde concentrate, UF Concentrate 85, to insolubilize starch has been reported to the 1956 and 1957 TAPPI Coating Conferences (*1, 2*). Briefly, these results showed that a urea-formaldehyde concentrate can provide the paper coater with an inexpensive material which may be used with starch-clay coatings to produce a coated paper having improved wet rub characteristics. This concentrate was effective when used with oxidized, dextrinized, hydroxyethylated, and enzyme modified starches. Improved wet rub resistance was obtained without the use of a catalyst. The concentrate was also used as an additive for size press applications to produce a sheet having improved wax pick and improved size tests.

Since these results were obtained from bench scale experiments and confirmed only by limited plant trials, it was apparent that further work should be done on a pilot coater operated under plant conditions. Accordingly, a grant-in-aid was established at the University of Maine for the work reported in this paper to be done under the direction of Professor L. C. Jenness and R. C. Chase.

G. K. Cleek, Allied Chemical Corp., Nitrogen Division, Hopewell, Va., and R. C. Chase, University of Maine, Orono, Me.

The utility of the urea-formaldehyde concentrate in paper coating lies in the fact that a large portion of the chemical reactivity of formaldehyde is passed on to its methylol derivatives so that they are normally included in the type reactions for formaldehyde. As far as the work in this paper is concerned, the most important type reaction of formaldehyde is with hydroxy compounds, as starch and cellulose, to form hemiacetals and methylene ethers or formals. These type reactions are modified by the effect of reaction conditions on the complex carbohydrate molecule and the various forms in which it is used. Under the influence of acid and high temperatures, stable resinous products involving chemical linkages of the starch and cellulose may be formed.

Experimental results indicate that the concentrate, UF Concentrate 85, is composed of methylolureas in equilibrium with free formaldehyde. All of the contained formaldehyde is available for further reaction. Thus, the same reactions which make formaldehyde and its methylol derivatives useful to the paper coater will apply to the use of the urea-formaldehyde concentrate.

To study the effect of pH, curing time, urea-formaldehyde concentration, and type of starch used on the degree of wet rub resistance produced on coated paper a series of trial coating runs on the pilot plant coater were made at the University of Maine. In addition to wet rub resistance, Dennison wax pick, IGT printability, and MIT fold tests were made on the coated paper.

The starches used in this work were provided by National Starch Products; the clays by Southern Clays and R. T. Vanderbilt Co.

PROCEDURE

Preparation of Starch

All runs were made with an adhesive concentration of 16 to 18% based on the weight of dry clay.

The starch was prepared by dissolving the desired weight in cold water and then heating to 190°F. in a double boiler. The starch was held at 190°F. for 30 min. and then cooled to room temperature. The solution was weighed and any water loss due to evaporation replaced. The Brookfield viscosity of the starch solution was measured as a check on the uniformity of the cooking procedure.

In the case of the enzyme-converted starch, a dry enzyme was used and the manufacturer's recommendations followed for cooking the starch and deactivating the enzyme. The starch was then cooled to room temperature, water loss made up, and the viscosity measured.

Mixing, pH Adjustment, UF Concentrate Addition

The dispersing agent used (0.25% TSPP based on dry clay) was added as 200 g. of a water solution to a sigma-blade mixer. Approximately 1800 g. of starch solution were added and then 7800 g. of clay were slowly added to the mixer. This doughlike clay mix was allowed to knead for 2 hr. At the end of this time the balance of the starch solution was added and the pH ajdusted to the desired value with a 10% solution of NH_4OH or HCl. The concentrate which had previously been adjusted to the desired pH value was then added, and any necessary water to give the final per cent solids was also added. The adjustment of pH and addition of the concentrate required approximately 30 min. At the end of this period the color was ready to be applied to the paper.

Roll Coater

The roll coater consists of a roll train of four rubber rolls having a 12-diameter and a 14-in. face. A back-up roll for the paper is the same size but is constructed of chromium plated steel. The speed of each roll in the roll train is adjustable so that the rate of shear in each nip can be

Table I. Summary of Runs Using Nadex 350 Starch

UF-85, % →	*15*			*15*			*15*			*25*			*25*			*25*			*35*			*35*			*35*		
pH →	*6.05*			*7.10*			*7.90*			*6.10*			*7.10*			*7.94*			*6.08*			*6.96*			*7.94*		
Cure time, sec. →	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*
Code →	*104*	*105*	*106*	*98*	*99*	*100*	*101*	*102*	*103*	*80*	*81*	*82*	*74*	*75*	*76*	*77*	*78*	*79*	*89*	*90*	*91*	*83*	*84*	*85*	*86*	*87*	*88*
Visc. starch																											
50 r.p.m.		18.9[a]			61.6[a]			29.2[a]			25.5[b]			34.4[b]			24.6[b]			26.5[b]			40.5[a]			55.0[a]	
100 r.p.m.		39.6			94.4			39.4			38.2			49.6			36.1			40.3			61.0			86.9	
Visc. color[c]																											
50 r.p.m.		44.1			43.2			37.4			41.0			34.3			36.0			34.4			35.4			47.9	
100 r.p.m.		61.1			56.2			49.5			50.5			43.5			45.0			48.6			45.4			64.0	
Solids, %		67.9			67.9			67.9			67.7			68.2			67.8			67.5			67.5			68.2	
Coat wt.		11.2			8.6			9.8			8.9			10.8			11.0			10.4			10.3			8.4	
Wax pick	7	7	7	8	8	8	8	8	8	7	7	7	7	8	7	7	7	7	7	7	8	8	9	8	8	8	9
							S.P.		S.P.					S.P.							S.P.	S.P.				S.P.		
Wet rub (av.)	10.8	11.8	13.0	9.5	13.7	15.5	10.1	13.2	14.5	17.2	21.1	26.2	13.9	19.8	22.8	17.6	23.9	25.1	12.5	13.9	16.0	15.4	17.0	24.1	9.6	10.0	12.9
MIT Fold (av.)	25.6	21.0	21.8	26.5	24.6	19.7	30.6	28.4	25.5	25.2	24.7	13.9	18.8	22.2	21.9	21.8	17.0	15.7	15.1	23.8	25.9	27.1	26.2	21.7	23.0	25.5	26 6
IGT	225	211	213	175	165	190	258	166	166	255	263	218	153	153	135	169	270	117	183	259	276	203	128	183	146	279	192

[a] Spindle No. 2. [b] Spindle No. 3. [c] Spindle No. 5.

Table II. Summary of Runs Using Amioca Starch

UF-85, % →	*15*			*15*			*15*			*25*			*25*			*25*			*40*			*40*			*40*		
pH →	*7.93*			*7.05*			*5.3*			*8.06*			*5.28*			*6.76*			*8.14*			*6.92*			*5.32*		
Cure time, sec. →	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*60*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*
Code →	*35*	*36*	*37*	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*52*	*53*	*54*	*55*	*56*	*57*	*58*	*59*	*60*	*61*
Visc. starch																											
50 r.p.m.		307			192			229			251			238			260			237			234			244	
100 r.p.m.		319			216			252			235			267			284			256			260			266	
Visc. color																											
50 r.p.m.		11,840			14,800			10,360			6,900			13,600			7,680			6,580			7,060			12,000	
100 r.p.m.		8,960			10,200			7,150			5,230			9,260			5,580			4,530			4,940			8,080	
Solids, %		70.0			71.0			69.1			69.7			69.2			69.4			69.1			69.2			69.5	
Coat wt.	12.8	12.3	10.6	12.7	13.0	11.6	11.5	11.5	11.1	9.3	9.6	13.4	13.3	12.0	10.0	19.0	12.1	15.1	8.8	10.2	14.5	11.2	10.9	9.3	11.2	11.8	10.4
Wax pick	7	7	6	6	6	6	6	6	6	6	6	7	6	6	7	6	6	6	7	7	7	7	7	7	7	7	7
Wet rub (av.)	20.3	19.0	17.7	21.3	23.0	24.3	20.7	18.3	16.7	27	42.7	75.0	21.7	32.7	43.3	18	17	19.3	17.3	22.3	27.7	16.3	16.3	32.3	15.7	21.7	29.3
MIT fold (av.)	19.8	18.7	13.3	17.3	18.7	37.7	43.3	30.5	46.7	52	14	25.3	17.3	20	22.3	15.5	9.3	9.3	12.3	9.7	6.0	14.3	9.3	13.7	10.7	12.7	14.0
IGT	272	248	328	294	290	260	265	222	344	378	397	395	303	300	300	552	590	530	438	450	525	530	525	515	485	505	565
MVT	274	263	273	254	260	273	253	210	188	185	340	294	386	251	370												

Table III. Summary of Runs Using Flowkote Starch

UF-85, % →	*15*			*15*			*15*			*25*			*25*			*25*			*35*			*35*			*35*		
pH →	*6.10*			*6.94*			*8.05*			*6.08*			*6.96*			*8.05*			*6.10*			*7.06*			*8.10*		
Curing time, sec. →	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*60*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*	*30*	*60*	*90*
Code →	*128*	*129*	*130*	*122*	*123*	*124*	*125*	*126*	*127*	*137*	*138*	*139*	*131*	*132*	*133*	*134*	*135*	*136*	*137*	*138*	*139*	*140*	*141*	*142*	*143*	*144*	*145*
Visc. starch[a]																											
50 r.p.m.		53.9			37.9			51.5			36.0			62.2			29.7			17.3			30.5			23.2	
100 r.p.m.		75.0			51.7			67.9			47.0			82.4			41.2			26.2			42.5			30.0	
Visc. color[b]																											
100 r.p.m.		36.0			28.2			32.3			17.5			32.6			31.8			18.0			23.4			17.4	
Solids, %		68.0			68.6			67.7			68.8			67.8			67.9			67.6			67.7			67.0	
Coat wt.		12.9			12.8			9.6			9.4			10.6			11.3			10.4			8.2			10.6	
Wax pick	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	5	5	6	5	6	5	6	7	6	5	5	5
Wet rub (av.)	21.8	23.9	28.2	21.8	23.4	22.4	20.9	23.4	23.0	21.0	24.5	26.3	20.9	24.2	24.8	20.9	22.0	29.6	20.4	21.1	23.7	21.7	23.9	26.3	29.1	31.2	31.9
MIT fold (av.)	21.0	22.6	23.2	17.5	18.7	20.4	18.5	18.4	18.9	21.5	23.0	23.4	21.3	23.5	22.8	18.7	20.6	22.6	15.4	21.3	21.0	20.8	22.5	23.2	18.4	22.2	23.0
IGT	183	243	263	228	213	251	140	195	183	170	190	299	185	241	239	178	221	239	196	206	206	139	220	204	93	176	159

[a] Spindle No. 2. [b] Spindle No. 7.

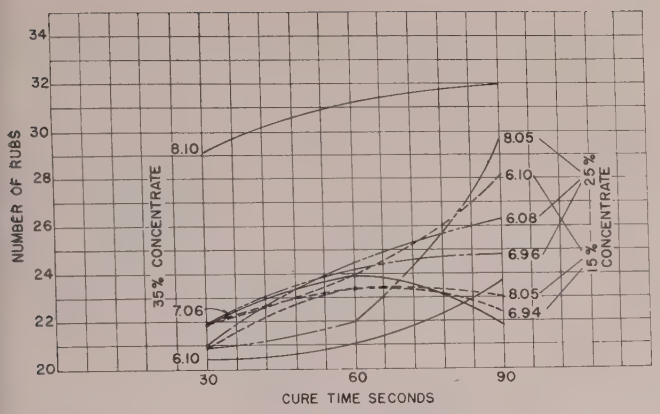

Fig. 1. Flowkote

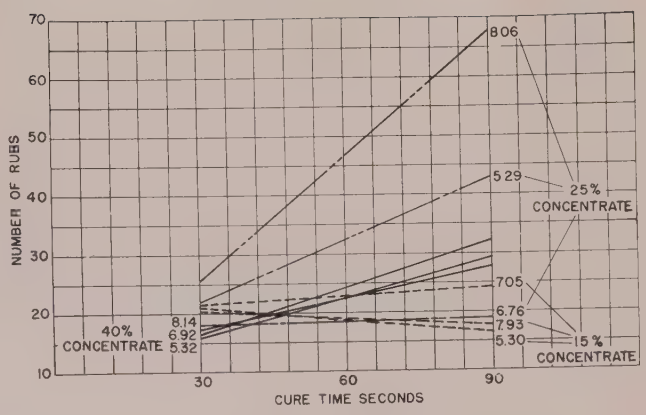

Fig. 3. Amioca

progressively increased until the coating color is applied to the paper.

The drying section consists of 4-ft. diameter, chrome plated drying cylinders using high pressure steam. The machine speed is continuously variable, from 50 to 750 f.p.m.

In operating the coater the machine was run at the desired operating speed (500 f.p.m.) and the coat weight adjusted by changing the pressure or rate of shear in the coating roll nips.

After the coat weight had been adjusted to a satisfactory value (10–12 lb., 25 × 38—500 on 41-lb. base stock) an experimental run was made. To simulate the effects of various drying times which might be observed in various mills, and to determine the effect of drying time on amount of reaction, the paper was taken from the rewinder and again passed over the driers. Samples were taken for testing at 30, 60, and 90 sec. of total contact time with the driers.

TESTING PROCEDURE

The basis weight was obtained by weighing ten 10 × 10-in. humidified sheets and multiplying by the appropriate conversion factor. The weight of the raw stock at approximately the same point in the roll was also obtained and the difference between the two was recorded as the weight of coating applied.

The MIT fold test was run in accordance with accepted procedures.

IGT printability tests were run on calendered sheets from each run. In all cases the speed and IPI tack graded ink used were adjusted so that pick first occurred in the initial third of the sample being tested. In most cases this involved the use of no. 2 ink (IPI tack graded black) and the use of the "A" speed on the IGT printability tester.

Wet rub tests were made using the wet rub tester manufactured by the American Instrument Co. With this instrument a variable speed motor is made to push a rubber finger over the surface of the coated paper. The paper is wetted with water from an eye dropper and the number of strokes required to break through the coated surface is recorded.

In addition the finger wet rub test was performed. Five drops of water were placed on the coated surface and allowed to penetrate for 30 sec. The bare finger was then rubbed across the wetted areas onto a sheet of black paper depositing on the black paper any coating which had not adhered to the coated paper. By shifting the coated paper slightly a series of seven of these forefinger wipes could be made and compar- the results compared visually.

In order to determine whether or not continued cure was obtained over a long period of time a selected series of coated paper samples was tested daily for a period of one month. The results obtained were assumed to be typical of those which would be obtained from any of the coated paper.

DISCUSSION OF RESULTS

Table I contains the tabulated average values of the original data for all three starches used in this work. Inspection of these data indicates that no significant change in wax pick value can be attributed to the use of the concentrate. The more highly converted starch had the lowest wax pick value; however, no trend or change can be seen within the runs made using any one starch.

It will also be noticed that moisture vapor transmission tests were run on the Amioca starch (Table II). This was done in order to determine whether a waterproof film was being formed. The evidence indicated that a film was not being formed and that while the use of the concentrate enhanced the wet rub resistance it had no effect on the moisture vapor transmission. This test was consequently omitted from the experimental results obtained with the other starches.

Figures 1, 2, and 3 show the effect of cure time on wet rub resistance as measured by the mechanical wet rub tester. Both pH and amount of concentrate used are parameters on these figures. The wet rub resistance is observed to increase with cure time and the increase in wet rub resistance is more pronounced with the more reactive starch. In all cases the use of 25% concentrate (by weight, based on weight of dry starch) shows an improvement over the use of 15%.

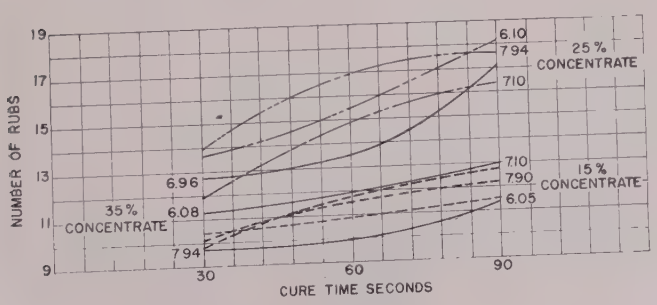

Fig. 2. Nadex 350

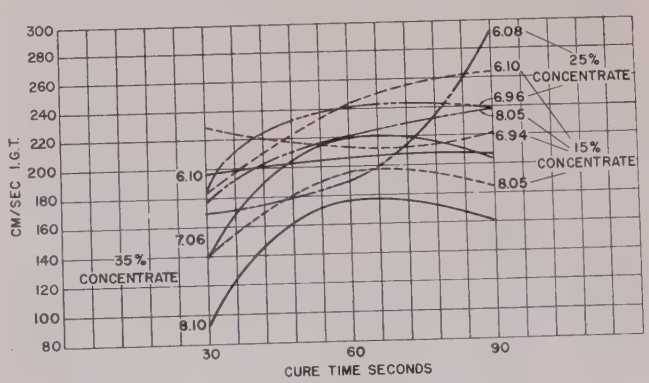

Fig. 4. Flowkote

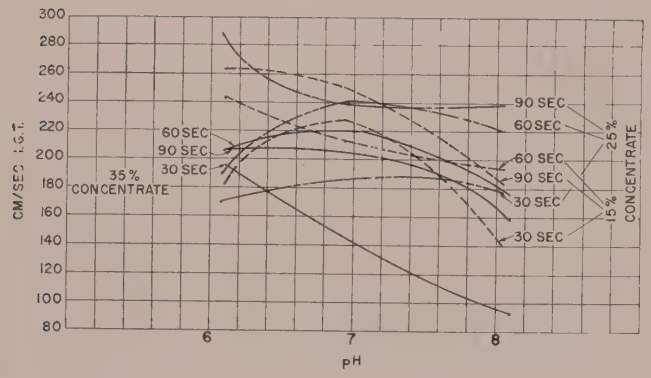

Fig. 5. Flowkote

Increasing the amount of concentrate to more than 25% has a varied effect and in general is probably not necessary to obtain the desired wet rub resistance.

The effect of pH on wet rub resistance is varied and does not appear to have any deleterious effect over the range of pH values investigated.

Figures 4 through 9 show the effects of pH, cure time, and amount of concentrate used on the printability of the coated paper. Figure 4 indicates that printability, as measured by the IGT printability tester, increases with increasing cure time. The addition of more than 25% concentrate appears to decrease the printability. Figure 5 indicates that the printability decreases with increasing pH and that the use of more

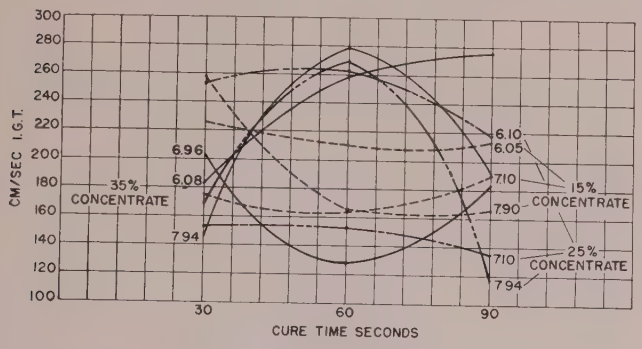

Fig. 6. Nadex 350

than 25% concentrate again has a tendency to lower the printability. Table III gives a summary of runs using Flowkote starch.

No safe conclusions can be drawn from Fig. 6. Figure 7 shows the same tendency as Fig. 5 and indicates that the printability decreases with increasing pH.

Figure 8 indicates that cure time has little effect on the more reactive Amioca starch; however, the printability is increased by the increased amount of concentrate used. Figure 9 again shows little effect of pH but does show the increase in printability due to increased amount of concentrate used.

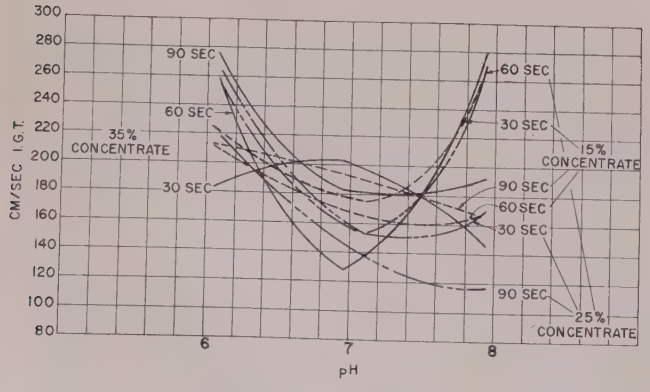

Fig. 7. Nadex 350

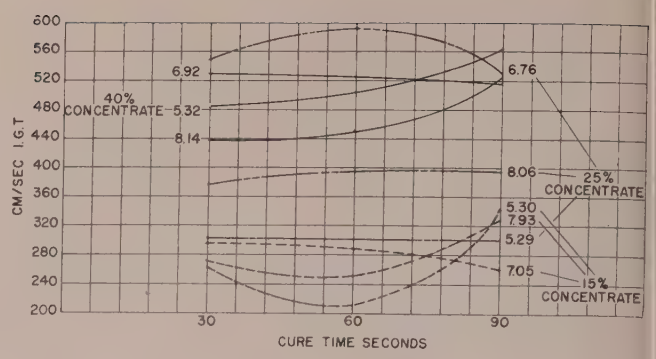

Fig. 8. Amioca

From a study of Fig. 1 through 9 it can be seen that the degree of reactivity of the concentrate with the starch depends upon the type of starch used but that in all cases its use increases the wet rub resistance and the printability of the coated paper.

Figure 10 shows the increase in wet rub obtained when a

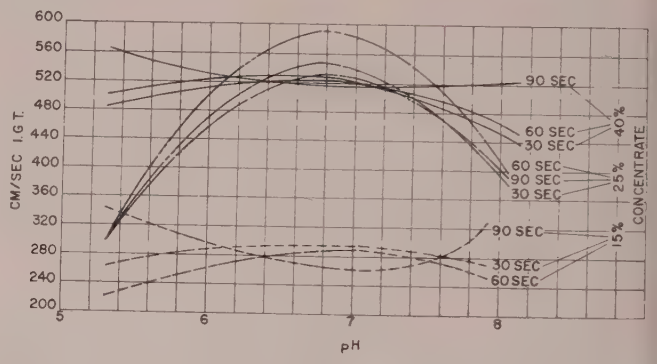

Fig. 9. Amioca

series of samples were allowed to age in a constant temperature and humidity room (70°F. and 50% R.H.) and were tested daily. A gradual increase in cure resulted in an increased wet rub resistance. No decrease in printability was detected.

MIT fold tests were run to determine whether or not the increase in wet rub obtained by using the concentrate had any effect on the folding characteristics of the coated paper. Since most of the folding strength comes from the base stock,

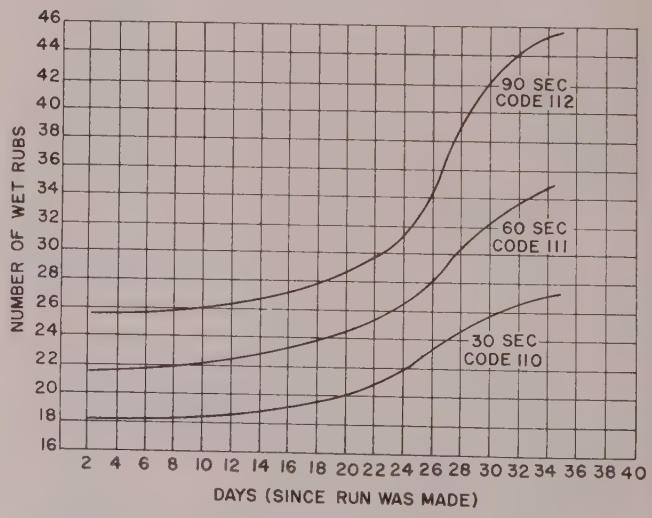

Fig. 10. Increase of wet rub resistance with time

the small differences found are not significant and no conclusions can be drawn from the MIT fold data in Table I.

CONCLUSIONS

The use of the urea-formaldehyde concentrate, UF Concentrate 85, to increase the wet rub resistance of paper coatings has been demonstrated to be feasible with a variety of commonly used starches on a laboratory coater under typical machine operating conditions.

In addition to increased wet rub resistance a considerable improvement in printability results form the use of this product.

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Titanium Dioxide Retention

H. C. BRILL and F. L. HECKLAU

My interest in this subject goes back some fourteen years to 1945 when I was given the assignment of setting up a paper laboratory for the testing of white pigments in paper. It was during my first call on a paper account that I became painfully aware that many people in the paper industry considered the price of titanium dioxide as excessively high. The price was then $14^1/_2$¢ and is $25^1/_2$¢ per lb. at the present time. Because of the relatively high manufacturing costs of titanium dioxide, it was unlikely that any major price reduction would occur. Our best chance of lowering the cost of the pigment to the paper manufacturer was in research designed to lower the unit cost through operating economies initiated in the customer's mill. The most likely spot to start was in the wet end of the paper machine by improving the retention of the pigment and thus reducing unit cost. Since that time, the writer has prepared several papers and talked numerous times on the subject. The paper to be delivered this evening should be considered in the light of a progress report since there are still many unanswered questions and unexplained phenomena to be investigated.

TITANIUM DIOXIDE RETENTION IN THE PAPER MILL

The amount of pigment found in the paper divided by the amount of pigment added at the headbox multiplied by 100 is considered "one pass retention." The amount of pigment in all the reels of a given run divided by the amount of pigment added at the wet end multiplied by 100 is considered by many mills as the "over-all retention." Although "over-all retention" of a high magnitude is more desirable than "one pass retention," we find that in actual practice it is very difficult to determine the "over-all retention" accurately. The majority of mills are unable to schedule one machine entirely on titanium dioxide filled papers. As a result, the runs are of short duration and the titanium dioxide in the white water before and after the run is unaccounted for in the determination. In a mill of this type, considerable titanium dioxide is lost to nonpremium or nontitanium dioxide containing grades. From a profit standpoint, a loss of this type is similar to pigment lost to the sewer. Since "over-all retention" requires the supervision of the technical staff, it is seldom run on a routine basis. On the other hand, "one pass retention" may be set up and run on a routine basis by the plant control laboratory. This figure coupled with the pounds lost to the sewer is sufficient to give management a good practical picture of the efficiency of their mill operation. High "one pass retention" smooths out fluctuations in paper quality, reduces the load on the save-alls and reduces the loss of titanium dioxide to nonpremium grades when small orders have to be run.

A well closed white water system with properly operated save-alls is the best retention aid a mill can secure, and it is a necessity if the mill wishes to add titanium dioxide in the wet end and compete with other manufacturers of this type of paper. Unfortunately, many things which cause poor retention on the paper machine cause the same trouble in the save-alls, so this is not a perfect answer to the retention problem.

A good accounting system is also a necessity, for it is surprising how few paper mills actually know what the titanium dioxide retention of a given machine and a given grade of paper is at the moment. A mill that purchases $100,000 per yr. worth of titanium dioxide, or more, can afford to assign one man full time to the difficult task of keeping accurate records on their use of titanium dioxide. Such a man should report at regular intervals to the mill manager on the following:

1. The pounds of titanium dioxide in the paper mill system at the beginning of a given time interval.
2. The pounds of titanium dioxide added to the paper mill system during the time interval.
3. The pounds of titanium dioxide in saleable premium paper manufactured during the time interval.
4. The pounds of titanium dioxide in saleable nonpremium paper manufactured during the time interval.
5. The pounds of titanium dioxide in the system at the end of the time interval.
6. The pounds of titanium dioxide lost to the sewer during the time interval.
7. The pounds of titanium dioxide that are unaccounted for during the time interval.

The most important calculation from the above data is the per cent of the total titanium dioxide found in salable paper. This figure is secured by dividing no. 3 by no. 2 and multiplying by 100. It is the best measure of a mill's efficient use of the pigment.

MECHANISM OF RETENTION

Fillers may be retained in the wet end of a paper machine by two basic mechanisms. These are electrostatic attraction between the filler and the fiber and simple mechanical filtration.

Electrostatic Attraction

Any dispersed solid in contact with water will assume an electric charge with respect to water. The sign and magnitude of this charge is dependent upon the adsorption of various ions from the water. In a rough way, solids tend to assume a negative charge under alkaline conditions and a positive charge under acid conditions. If the solid is small enough and the charge large enough, a particle with a given charge will tend to migrate toward an electrode of the opposite sign (electrophoresis). Commercial forms of water dispersing titanium dioxide have a negative charge in distilled water, and this is readily determined by inserting two electrodes into a dispersed pigment slurry. The pigment will migrate to and plate out on the positive electrode. However, cellulose also has a negative charge over most of the pH range. As a result, the retention of a negatively charged titanium dioxide slurry in a handsheet made from wood pulp in distilled water is essentially zero.

The retention of certain dyes and wet strength resins is apparently accomplished by electrostatic attraction. The particle size of these solids is in the colloidal range and much smaller than normal pigment dimensions. Some years ago, the writer prepared some colloidal titanium hydrate and gave it a positive charge by dispersing it at low pH with hydrochloric acid. This dispersion was very stable and remained in

H. C. Brill and F. L. Hecklau, Technical Service Lab., E. I. du Pont de Nemours & Co., Inc., Pigments Dept., Chestnut Run, Wilmington 8, Del.

suspension for several years without observable settling. The one-pass retention of this material in handsheets was outstanding, but it did not improve the optical properties of the paper. Certain forms of pigmentary titanium dioxide may also be given a positive charge by dispersing them with aluminum chloride. Unfortunately, the charge per unit particle weight is small and they do not retain well in paper. Attempts to increase this charge by reducing the particle size resulted in a loss of optical properties without an appreciable improvement in retention. The optimum particle size of titanium dioxide for the best optical properties is a narrow band near 0.2 μ, and any attempt to move in either direction results in a major loss of opacity and brightness. As a result of the above experiments, it did not appear probable that one could give pigmentary titanium dioxide a positive charge per unit particle weight of sufficient magnitude to secure paper retentions of the same order as those achieved by agglomeration and mechanical filtration.

Mechanical Filtration

It is most probable that the retention of commercial titanium dioxide in the wet end of a paper machine under the conditions of use that are now practiced is a combination of electrostatic and mechanical filtration. The neutralization of the negative charge of the pigment by alum addition is electrostatic in nature, but the retention of the resulting uncharged agglomerate is apparently mechanical. An increase in retention may be secured by increasing the agglomerate size; reducing the paper pore size by increased pulp hydration; use of gelatinous materials such as freshly formed aluminum hydrate; use of needlelike fillers, such as diatomaceous silica. These methods of improving pigment retention function by reducing the pore size of the filter mat of pulp fiber or increasing the effective size of the agglomerates. When we speed up a paper machine, it is necessary to increase the suction on the filter boxes and the couch roll. As a result of increased mechanical force on the pigment, the one pass retention is reduced. In a similar way, an increase in basis weight results in a thicker filter mat and better retention. Some pulps form a less porous filter mat than others and give better retention of fillers as a result. A general rule to follow in judging the effect of various chemicals or machine operations for filler retention is to determine whether these changes affect agglomerate size or wet pulp fiber porosity. An increase in the former increases retention and a decrease in filtration pore size will increase retention, and vice versa.

The initial size of the titanium dioxide pigment is well below the pore size of the ordinary paper filter mat and the pigment will readily pass through this mat in the dispersed form. After addition of alum or other flocculation agents, these particles are agglomerated into a much larger size particle. "One-pass retention" is determined by the size of these agglomerates when they reach the wire rather than the initial dispersed size or the initial agglomerate size upon flocculation. This progress report will deal primarily with methods of controlling agglomerate size so that the titanium dioxide pigment will arrive at the wire in a form that will give the paper the best combination of retention and optical properties.

EFFECT OF DISPERSANTS AND PROTECTIVE COLLOIDS ON THE RETENTION OF TITANIUM DIOXIDE

Willetts (*1*) discovered in 1935 that starch had a detrimental effect on the "one-pass retention" of titanium dioxide, and theorized that this was probably due to a protective colloid behavior which prevented the agglomeration and resulting particle growth necessary for retention. The writer (*2*), in 1955, found that most cornstarches were detrimental to the retention of titanium dioxide and that a chlorinated cornstarch nullified the advantages of most retention agents. The troubles arising from the use of cornstarch have been well

Table I. Effect of Concentration on Retention of Titanium Dioxide

Experiment no.	*Chlorinated starch, %*	*Digestion after agitation*	*TiO_2 retention, % pulp consistency at flocculation*	
			0.5%	*4.0%*
1	None	10 min.	37	43
2	None	30 min.	42	46
3	None	1 hr.	47	46
4	None	2 hr.	50	50
5	None	5 hr.	54	55
6	2	10 min.	9	15
7	2	30 min.	9	16
8	2	1 hr.	9	15
9	2	2 hr.	9	16
10	2	5 hr.	8	17

publicized and have tended to obscure the fact that many other starches and other organic agents can and do function in the same way. It seems probable that the aluminum ion is adsorbed on to the surface of the pigment or into the micelle during the flocculation phenomenon. Apparently, the starch molecule is more strongly adsorbed than the aluminum ion and displaces it at the surface with a redispersion of the flocculated pigment. With adequate time and agitation, it apparently makes little difference in retention what the order of addition of the chemicals may be.

The use of starch and other dispersants in the paper mill operation is so common that it is impossible to keep them out of the wet end. Although it is possible to stop their direct addition, they will get in from broke which has had starch added at the size press or in coating. Therefore, it is desirable that we investigate the fundamental conditions of manufacture in the interval between the point of addition of the pigment and the wire, on the flocculate size and the resulting retention. This will be done both in the presence and in the absence of starch. These variables are: (1) the concentration of the reactants and the amount of alum addition; (2) the effect of violent agitation of the same order as one might get from the beater, refiners or pumps in the wet end, and the time between agglomerate formation and incorporation into the paper; (3) the effect of clay concentration; (4) the effect of dilution after flocculation; and (5) the effect of temperature.

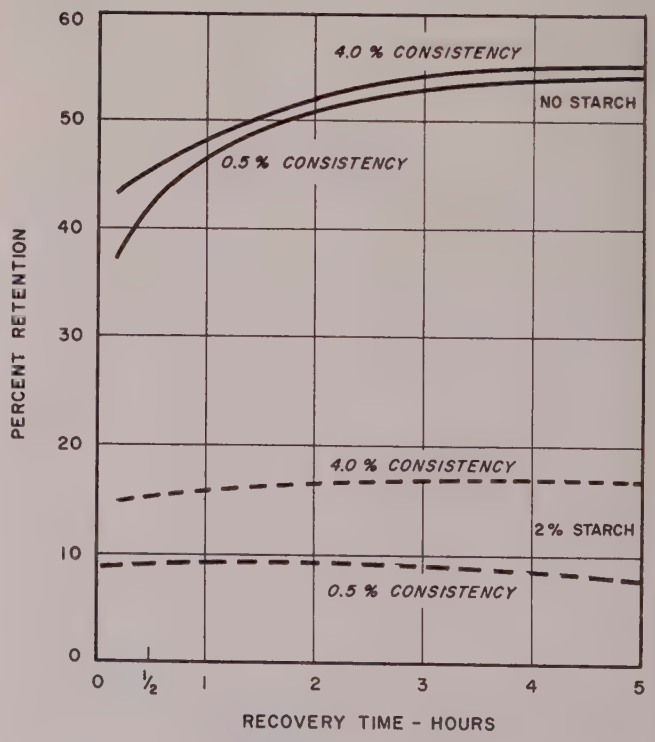

Fig. 1. Effect of concentration on retention of titanium dioxide

Table II. Effect of Alum Addition on Retention of Titanium Dioxide, 0.5% Pulp Consistency

Expt. no.	Chlorinated starch, %	Alum concentration, %	pH	TiO_2 retention, %	TAPPI brightness, %	TAPPI opacity, % Unwaxed	TAPPI opacity, % Waxed
1	None	0	6.2	12	83.7	80.3	32.3
2	None	1	4.8	34	85.5	83.7	50.1
3	None	2	4.5	39	84.8	85.5	52.8
4	None	4	4.2	41	86.2	84.8	53.5
5	None	6	4.1	41	86.6	84.8	53.4
6	None	8	4.1	39	86.5	85.0	52.8
7	2	0	6.2	5	83.6	78.8	23.3
8	2	1	4.8	8	85.1	79.6	27.4
9	2	2	4.5	16	85.2	81.0	37.9
10	2	4	4.2	26	86.0	82.0	43.0
11	2	6	4.1	28	86.0	82.4	44.8
12	2	8	4.1	35	85.9	83.2	47.6

The Amount and Concentration of the Reactants, and the Amount of Alum Addition

Table I and Fig. 1 illustrate the effect of flocculating titanium dioxide at the concentrations of the beater compared with those found at the headbox. In this experiment, we subjected the flocculates to severe agitation and also ran the experiment in the presence and absence of starch. The data and the curves show that we get a better retained flocculate at the higher concentration and also one that is more resistant to the attack by starch and agitation. We changed the conditions of this experiment in Table II, Table IIa, Figs. 2, 2a, 2b, and 2c. Here the agitation was eliminated, and you will note that the general level of retention of the starch-containing furnishes is much higher. Comparison of Fig. 2 with Fig. 2b shows that retention, both with and without starch, is higher at the 4% consistency level than at the 0.5%. These data show that if all other factors were equal, it is preferable to flocculate the pigment at the high concentrations found in the beater rather than the lower concentrations of the headbox. However, in practical applications, other factors do enter the picture and in later experiments we will show that this is not always correct.

It is rather difficult to distinguish between the amount of the reagents in the flocculation reaction and the concentration, since the two are related. However, it is theoretically possible to use a concentrated slurry of titanium dioxide and flocculate this outside the paper system with a concentrated solution of alum. The resulting mixture could then be pumped to the paper system in a flocculated form and compared in retention with flocculates prepared with the same amount of reagents but at the lower concentration of the paper mill system. Outside flocculation would cause some difficult practical problems in the storage, pumping, and metering of a flocculated system, but the data mentioned in the previous paragraph indicates that we might get higher retention and a flocculate that was more resistant to breakdown by both starch and agitation.

Under practical conditions, the amount and concentration of the alum flocculating agent is the one most readily changed. For this set of experiments, we reduced the agitation to a mild stirring; varied the concentration level between 4 and 0.5% consistency and changed the amount of alum added from 0 to a maximum of 8%. Under these conditions, it is apparent that the optimum alum addition is approximately 2% where starch is absent, and when starch is present the retention is still climbing at the 8% level. The curve is particularly sharp on the retention curve with starch at the 0.5% consistency level. We were curious if the 8% level of alum addition might have overflocculated the pigment and caused a loss of optical efficiency. Comparison of the curves in Fig. 2 versus Fig. 2a, also Fig. 2b versus 2c shows that they are roughly similar. This indicates that no significant overflocculation occurred. This set of experiments with alum also show the effect of concentration level since the retention both with and without starch was higher at the 4% consistency level than at the 0.5% level.

The Effect of Violent Agitation and Time of Recovery

It is common practice to put the titanium dioxide into the beater, flocculate it here with alum, and subject the resulting agglomerates to severe attrition during the beating cycle, refining cycle, cleaning, and pumping before bringing them to the wire. We suspected that this violent agitation might alter the agglomerate size and the resulting retention. This experiment compares two furnishes with and without agitation, and with and without starch. We also investigated the effect of recovery time on retention by following the retention of these agitated furnishes over a period of several hours. The data shown in Table III and Fig. 3 show the following:

1. The retention is essentially unaffected by severe agitation if there is no starch or dispersant present.
2. Where starch is present, agitation reduces retention to a minimum level immediately. The unagitated control approaches the same level as the agitated sample if given sufficient time.
3. Where starch is absent, the agitated and the unagitated flocculates tend to improve in retention with time at approximately similar rates.

These data illustrate the difficulty of getting reproducible retention results on experimental runs in either the plant or hand sheet mold. Many investigators have failed to control the severity of agitation and the time between agitation and the finished paper. In effect, one is always trying to hit a moving target.

Table IIa. Effect of Alum Addition on Retention of Titanium Dioxide, 4.0% Pulp Consistency

Expt. no.	Chlorinated starch, %	Alum concentration, %	pH	TiO_2 retention, %	TAPPI brightness, %	TAPPI opacity, % Unwaxed	TAPPI opacity, % Waxed
13	None	0	5.8	25	86.1	81.1	42.5
14	None	1	3.9	52	87.8	85.1	56.6
15	None	2	3.7	51	87.3	84.9	56.0
16	None	4	3.6	53	87.6	85.0	56.5
17	None	6	3.3	51	87.8	84.8	55.9
18	None	8	3.3	56	87.6	85.1	57.2
19	2	0	5.8	20	85.7	80.2	38.9
20	2	1	3.9	29	87.3	81.9	45.5
21	2	2	3.7	32	87.4	82.6	47.7
22	2	4	3.6	36	87.4	82.8	48.7
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24	2	8	3.3	40	87.2	82.9	50.0

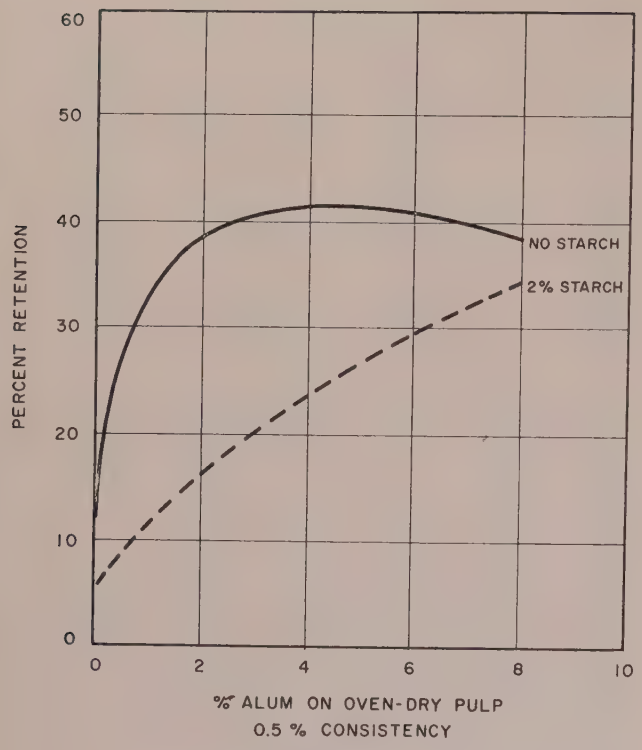

Fig. 2. Effect of alum addition on retention of titanium dioxide

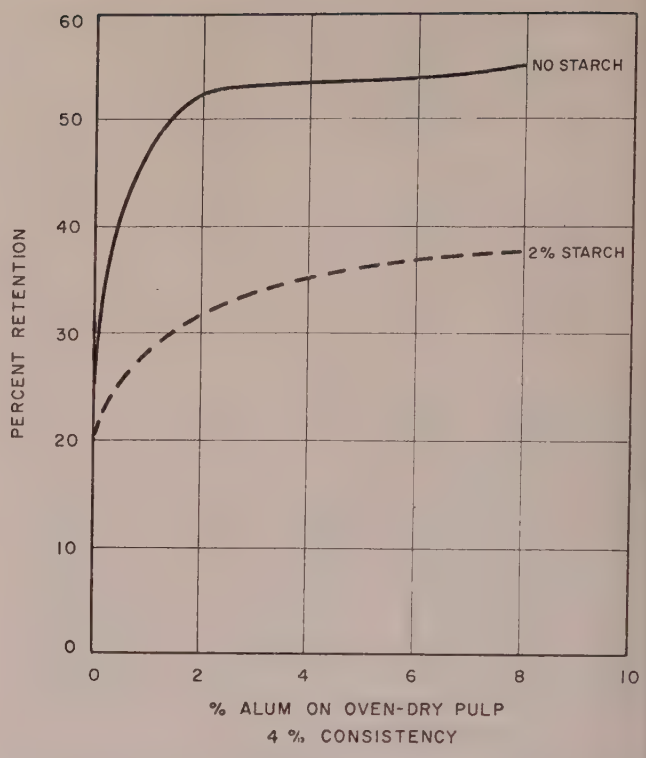

Fig. 2b. Effect of alum addition on retention of titanium dioxide

The Effect of Clay Addition on the Retention of Titanium Dioxide

Clay is the major filler in most papers, and titanium dioxide is a minor component. When the clay content of a sheet of paper is increased at constant basis weight, the effect on the titanium dioxide retention depends on the relative retention characteristics of the clay versus the pulp. The results shown in Table IV indicate that the clay had essentially the same filtration characteristics as the pulp since there is no appreciable change in the retention in the presence or absence of starch as the clay content of the paper was increased. It seems probable that the pulp might be mechanically refined so that it would be greatly superior to the clay, but this was not the case in our experiments.

It is of interest to note that the retention of the clay is markedly inferior to the retention of the titanium dioxide, which confirms the statements of other investigators (*1*). It is also of interest that the clay retention does not suffer as great a percentage loss upon starch addition as the titanium dioxide.

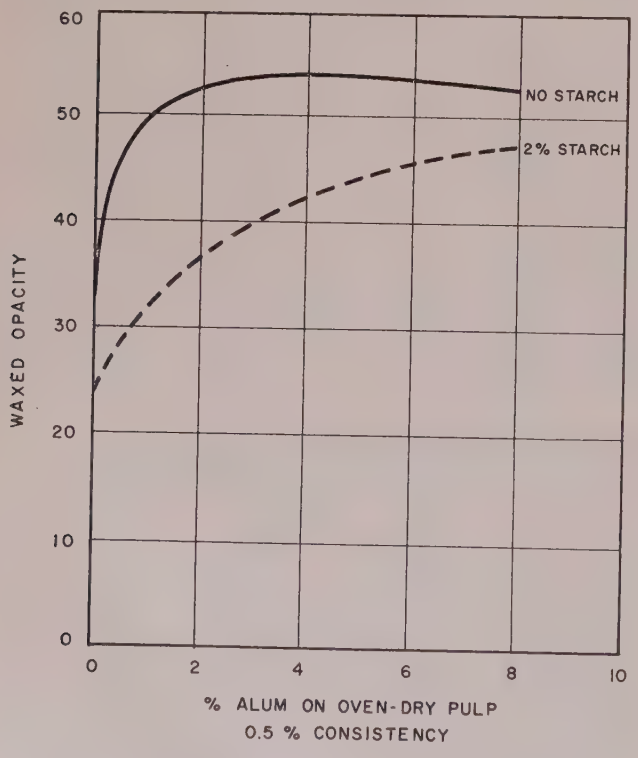

Fig. 2a. Effect of alum addition on waxed opacity

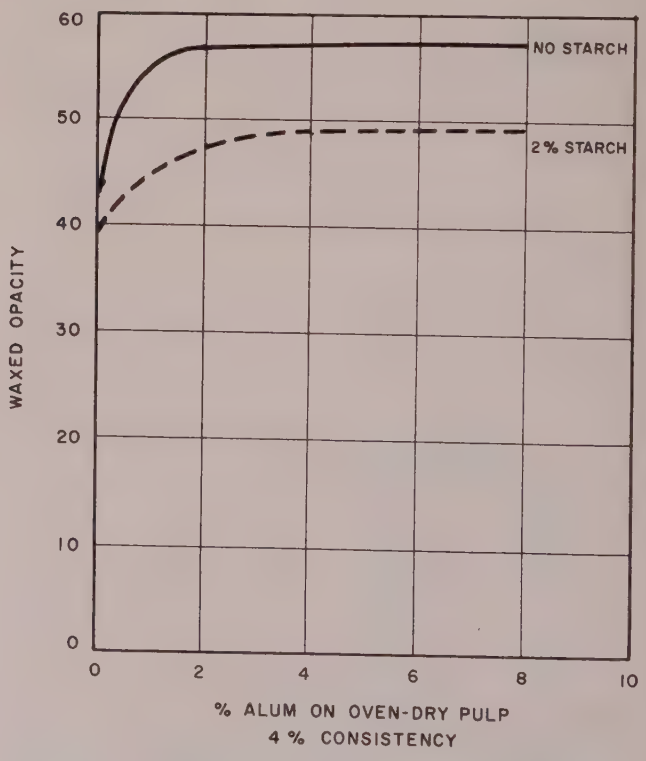

Fig. 2c. Effect of alum addition on waxed opacity

Table III. Effect of Agitation and Recovery Time on Retention of Flocculated Titanium Dioxide

Expt. no.	Chlorinated starch, %	Agitation after flocculation	TiO_2 retention, % Digestion after agitation 10 min.	30 min.	1 hr.	2 hr.	5 hr.
1	None	No	39	45	45	51	58
2	None	Yes	37	42	47	50	54
3	2	No	19	17	14	14	12
4	2	Yes	9	9	9	9	8

The Effect of Dilution After Flocculation

It is standard practice in paper mills to beat and refine the furnish at 4 to 6% consistency, and then dilute the furnish to approximately 0.5% before going to the wire. We were interested in determining what effect this dilution might have on retention since it is standard practice, and we were also interested in the effect it might have on a separately flocculated titanium dioxide slurry made at high concentrations of

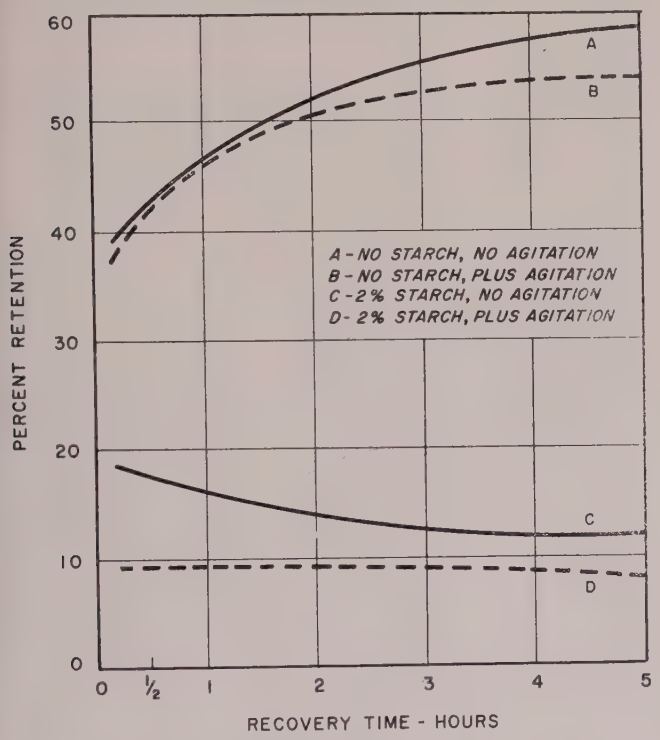

Fig. 3. Effect of agitation and recovery time on retention of titanium dioxide

reactants. Our normal procedure for making handsheets requires dilution to approximately 0.05% consistency in order to get satisfactory appearance and formation. We found out by trial and error that 0.75% consistency was the maximum level that we could use experimentally and get anything that looked like paper. We made a ladder starting at 0.75% with increasing dilution to 0.05%, and determined the per cent retention of various titanium dioxide levels in the presence and absence of starch. The data shown in Table V indicate that there is no change in retention upon dilution in the absence of starch and a slight retention loss in the presence of starch. These data would indicate that the possibility of external flocculation of concentrated titanium dioxide slurries with concentrated alum, followed by dilution and metered addition to the furnish, should be investigated further.

The Effect of Temperature on the Retention of Titanium Dioxide

We considered the effect of temperature as of lesser importance than the previous variables studied, but thought it desirable to round out the study. We selected the temperature of 35°F. as the minimum one might encounter in winter-operation, and the temperature of 77°F. as average for the summer months. We selected 190°F. as the maximum that a mill might try for securing rapid water removal on the wire. The experiments were made both with and without starch, Table VI, Fig. 4. They show that no appreciable change in retention should occur, with or without starch from winter to summer. A slight retention drop occurred between 77°F. and 190°F. without starch, and a major drop with starch. In general, a slightly decreased retention occurs as the temperature is elevated. This experiment was run with the pigment flocculated separately from the pulp, so that the results were unaffected by the fiber behavior. This may explain the difference in results secured by Willets (*1*). We shall have to repeat this experiment and compare co-flocculation with separate flocculation under different temperatures.

TITANIUM DIOXIDE, OPTICAL EFFICIENCY, AND OVERFLOCCULATION

Our laboratory has seldom encountered difficulty with overflocculation and the resulting loss of optical efficiency. In general, we were more concerned with loss of retention due to inadequate size flocs caused by the presence of dispersants or protective colloids. However, chemical manufacturers are now supplying a number of highly efficient flocculants, and one manufacturer of titanium dioxide is supplying a treated pigment with the ability to flocculate in the presence of starch and other dispersants. The general recommendation for the use of these new acrylic polymer flocculating chemicals is

Table IV. Effect of Clay Addition on Retention of Titanium Dioxide

Expt. no.	Chlorinated starch, %	TiO_2 added, %	Clay added, %	TiO_2 in sheet, %	TiO_2 retention, %	Clay in sheet, %	Clay retention, %	TAPPI opacity, % Unwaxed	Waxed
1	None	None	None	0.0	0	0.0	0	78.0	18.2
2	None	7	0	2.6	37	0.0	0	85.4	54.1
3	None	7	20	2.6	37	2.5	13	86.2	56.0
4	None	7	33	2.5	36	3.9	13	87.0	56.3
5	None	7	50	2.4	35	5.1	12	86.7	55.2
6	None	7	67	2.3	34	6.4	11	87.1	54.9
7	None	7	100	2.2	34	8.6	11	86.0	53.2
8	None	7	200	1.8	30	14.5	10	86.6	52.2
9	2	7	0	0.5	7	0.0	0	80.6	29.3
10	2	7	20	0.5	7	1.7	10	81.9	29.8
11	2	7	33	0.5	7	2.6	9	81.2	28.6
12	2	7	50	0.5	8	3.9	9	82.1	30.1
13	2	7	67	0.6	9	4.6	8	82.2	30.5
14	2	7	100	0.6	9	6.7	8	79.3	29.9
15	2	7	200	0.5	8	10.3	7	80.9	30.2

Table V. Effect of Water Dilution on Retention of Titanium Dioxide

Expt. no.	Chlorinated starch, %	Pulp consistency at wire, %	2% TiO_2 addition: TAPPI waxed opacity, %	2% TiO_2 addition: TiO_2 retention, %	7% TiO_2 addition: TAPPI waxed opacity, %	7% TiO_2 addition: TiO_2 retention, %	15% TiO_2 addition: TAPPI waxed opacity, %	15% TiO_2 addition: TiO_2 retention, %
1	None	0.75	...	50	...	58	...	59
2	None	0.50	...	47	...	53	...	70[a]
3	None	0.10	41.4	46	59.7	54	66.9	56
4	None	0.05	41.9	51	61.0	60	67.9	59
5	2	0.75	...	30	...	34	...	33
6	2	0.50	...	29	...	25	...	27
7	2	0.10	32.8	26	44.0	24	53.7	25
8	2	0.05	33.2	22	44.4	23	53.9	24

[a] In view of other data obtained, this high value is probably in error.

addition at the headbox or the fan pump in order to bypass the agitation of the beater, refiners, and cleaners. The experiments shown in Table VII, Figs. 5, 5a, and 5b were planned to study the possibility of overflocculating regular water dispersing titanium dioxide with alum and one of the new acrylic acid-type flocculating agents where agitation is omitted.

The pigments were flocculated in the absence of pulp in order to secure results unaffected by fiber behavior. We were able to visually observe by microscopic examination of the agglomerates both before and after hand sheet preparation that we had increased the agglomerate size. After waiting a suitable time for maximum agglomeration to occur, the pigments were added to the pulp in the absence of starch and agitation, and handsheets were made of low basis weight 25 lb. (25 × 40—500). The low basis weight was used in this experiment so that we might examine the agglomerate size in the resulting handsheets under the microscope. The curves show that it is possible to overflocculate titanium dioxide with alum alone. Combined with a special chemical flocculant, the optical efficiency is reduced to an even greater extent. This loss of optical efficiency is most readily followed by determining the waxed opacity, since this depends almost entirely on the amount and condition of the titanium dioxide agglomerates. It can also be followed by determining the TAPPI dry opacity and dry brightness, although neither of these tests are as critical as the opacity. Since the waxed opacity is a general indication of the ink showthrough properties of the paper, it seems likely that a paper manufacturer can lose much of the advantages of titanium dioxide addition by overflocculation with the tools now available.

It has been repeatedly proved that the maximum dispersion of titanium dioxide pigment gives the maximum opacity in a low pigment concentration oil system. However, in predominately air interface systems, it seemed probable that a slight amount of flocculation might give superior dry opacity and dry brightness because of greater surface exposed to the air. Curve A in Figs. 5, 5a, and 5b was secured with a completely dispersed titanium dioxide. You will note that under the conditions of our experiment it is inferior to the flocculated titanium dioxide curves B and C in dry opacity, dry brightness, and also waxed opacity. The poorer waxed opacity was surprising. It may be due to greater packing of the dispersed pigment in the paper pores, or the flocculated pigments may be more efficient because they still retain some air within the agglomerated particle.

Table VI. Effect of Temperature on Retention of Titanium Dioxide

Expt. no.	Chlorinated starch, %	Temperature at flocculation, °F.	TiO_2 retention, %	TAPPI opacity, % Unwaxed	TAPPI opacity, % Waxed
1	None	35	13	65.8	31.9
2	None	77	12	65.0	31.5
3	None	190	10	66.6	33.3
4	3	35	7	57.2	20.0
5	3	77	5	58.0	20.7
6	3	190	3	55.4	13.8

SUMMARY

The data in this paper indicate that:

1. The concentration and the amount of reactants present at the time of flocculation do affect the size, the resistance to agitation and the resistance to dispersion by starch of the agglomerates.

2. Severe agitation will markedly reduce the retention of titanium dioxide if starch is present. It does not markedly affect the retention in the absence of starch. Retention of titanium dioxide will increase as the time between flocculation and the wire is increased in the absence of starch. On the other hand, a loss of retention with time occurs in the presence of starch.

3. An increase in the clay content of the sheet did not appreciably change the retention of the titanium dioxide in the presence or absence of starch under the conditions of our experiments. Starch has a greater effect on the retention of titanium dioxide than on clay.

4. The dilution of the furnish following flocculation did not change the retention appreciably in the absence of starch, and only reduced retention to a slight extent in the presence of starch.

5. Increased temperature was found to change the retention slightly downward in the presence of starch, but had no appreciable effect in its absence.

6. The optical efficiency of titanium dioxide can be seriously impaired by excess flocculation. A slightly flocculated

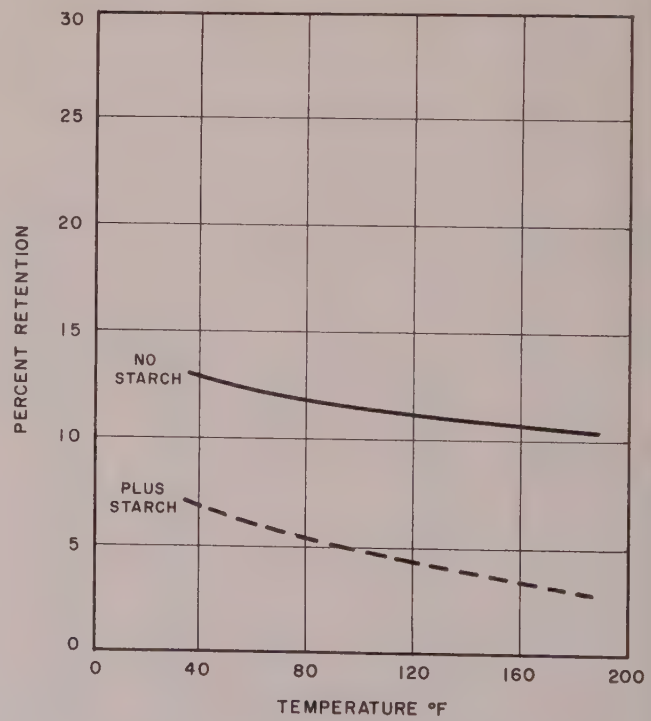

Fig. 4. Effect of temperature on retention of titanium dioxide

Table VII. Effect of Flocculation Degree on Optical Efficiency of Titanium Dioxide

Expt. no.	Curve letter	Alum addition on TiO_2, %	Retention aid on TiO_2, %	TiO_2 in sheets, %	TAPPI brightness, %	TAPPI opacity, % Unwaxed	TAPPI opacity, % Waxed
Control	..	None	None	None	82.4	57.7	12.9
1	A	None	None	0.6	83.7	58.9	19.0
2	A	None	None	2.4	85.5	65.8	36.0
3	A	None	None	4.2	86.4	71.1	43.3
4	A	None	None	9.1	87.6	78.5	56.0
5	B	4.0	None	0.7	84.4	59.9	22.2
6	B	4.0	None	1.9	86.1	66.0	36.9
7	B	4.0	None	3.2	86.8	70.1	43.7
8	B	4.0	None	5.4	87.4	75.2	52.5
9	..	8.0	None	0.7	84.0	61.4	22.9
10	..	8.0	None	2.2	85.6	66.9	37.8
11	..	8.0	None	3.4	85.3	71.8	45.3
12	..	8.0	None	6.8	86.1	76.4	53.6
13	C	20.0	None	0.4	83.2	60.3	19.1
14	C	20.0	None	1.4	84.6	64.9	31.2
15	C	20.0	None	2.5	85.3	69.0	39.3
16	C	20.0	None	3.5	85.7	71.3	45.1
17	C	20.0	None	5.5	86.7	74.2	49.7
18	D	20.0	0.4	0.6	84.0	60.3	19.9
19	D	20.0	0.4	1.5	84.8	63.2	28.4
20	D	20.0	0.4	2.9	85.8	68.6	38.9
21	D	20.0	0.4	4.0	85.9	69.9	42.6
22	D	20.0	0.4	6.9	86.5	75.4	51.7
23	E	20.0	0.8	0.4	83.6	58.9	16.1
24	E	20.0	0.8	1.0	84.0	60.7	22.1
25	E	20.0	0.8	2.1	84.6	63.6	29.8
26	E	20.0	0.8	3.1	85.3	67.0	36.9
27	E	20.0	0.8	6.4	86.7	74.1	50.1
28	..	20.0	2.0	0.3	83.7	58.9	16.3
29	..	20.0	2.0	1.0	84.0	60.7	20.6
30	..	20.0	2.0	2.0	84.1	63.0	26.4
31	..	20.0	2.0	2.9	84.3	63.6	31.0
32	..	20.0	2.0	6.1	86.4	72.6	47.6
33	..	20.0	4.0	0.4	82.9	57.4	16.1
34	..	20.0	4.0	0.9	83.5	59.2	20.5
35	..	20.0	4.0	1.9	84.1	63.0	28.3
36	..	20.0	4.0	2.9	83.8	65.1	33.6
37	..	20.0	4.0	5.5	86.6	69.7	43.4
38	F	20.0	8.0	0.6	82.9	57.9	16.2
39	F	20.0	8.0	1.0	83.3	60.1	20.8
40	F	20.0	8.0	1.6	83.2	61.6	25.9
41	F	20.0	8.0	3.8	84.0	65.1	34.9
42	F	20.0	8.0	6.0	85.1	70.0	43.3

pigment was more efficient optically than a dispersed one under the conditions of our experiment.

The data presented indicate that the paper manufacturer can materially change his titanium dioxide retention by selecting the conditions of the flocculation and point of pigment addition. It also indicates that he now has the tools to secure a degree of flocculation that is so great that the optical efficiency of the pigment is impaired. There is a maximum pigment agglomerate size one can use without loss of optical efficiency. The pulp hydration, basis weight, suction, and other mechanical factors decide the retention attainable with this optimum agglomerate size. It seems probable that every paper machine has a maximum "one pass" retention which cannot be exceeded without a serious loss of optical efficiency.

MATERIALS AND METHODS

The pulp used throughout this study was bleached sulfite secured from a west coast supplier. For the purpose of laboratory control, distilled water was used in all tests. The pulp was beaten in a Noble & Wood cycle beater at a 40% consistency to a freeness of 32°S.-R. All paper was made on a Noble & Wood sheet machine. Basis weights given are for a standard TAPPI ream, 25 × 40—500, on an oven-dry basis. Unless otherwise specified, all handsheets were made at a 50-lb. TAPPI ream basis weight.

The order of addition of the various materials, unless otherwise specified in the individual sections of this study, was pulp, followed by the pigment, starch, and alum. The order of addition of retention aids is discussed in the sections where used.

The starch used was a commercial grade of chlorinated cornstarch, cooked at 20% solids in water at 185°F. for 5 min. after clarification.

Where agitation of the furnish was included, this was accomplished with a Williams heavy-duty stock breaker before transferring the furnish to the proportioner for further dilution. After thorough mixing in the proportioner, 8 by 8-in. handsheets were made with further dilution in the deckle box to 0.03% pulp consistencies. These sheets were then calendered at 500 lb. per lineal in. at 180°F.

Except when investigating the effect of temperature on titanium dioxide flocculation, all evaluations in this study were carried out at 75°F. ± 3°.

The titanium dioxide pigment used in this study was regular water dispersing type. The pigment content in the sheets was determined by ashing and weighing against unpigmented control ash figures, except where clay filler was used. In this instance the sheets were ashed, and the ash was analyzed for titanium dioxide content by colorimetric methods. Pigment retention was calculated from the weight of titanium dioxide added and the weight retained.

TAPPI Standard T 452 m-48 was used to determine all brightness data with a G.E. brightness tester. Opacity values were determined on a Bausch & Lomb Opacimeter under test conditions specified in TAPPI Standard T 425 m-44. To obtain waxed opacity and waxed brightness data, all sheets were dried and immersed for 6 min. in a paraffin-microcrystalline wax blend (70% paraffin, 30% microcrystalline wax) at 205°F. ± 5° to the point of saturation. Excess surface wax was then removed by passing the sheets between heated pressure rolls.

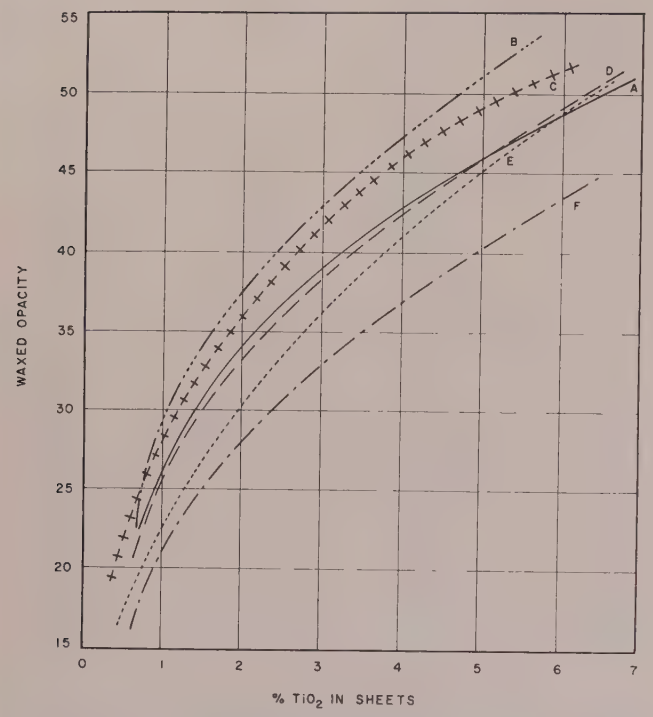

Fig. 5. Effect of flocculation degree on optical efficiency of titanium dioxide

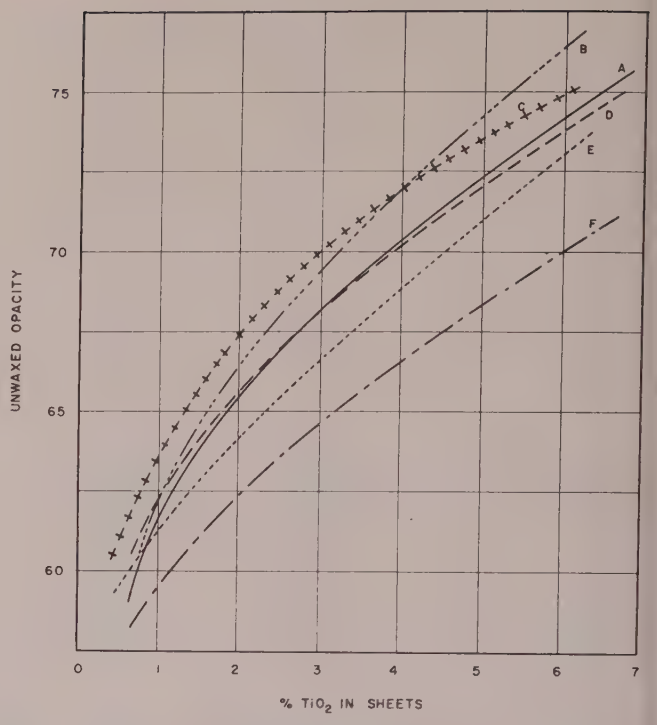

Fig. 5b. Effect of flocculation degree on optical efficiency of titanium dioxide

Effect of Concentration (Tables I, II, IIa, and Figs. 1, 2, 2a, 2b, 2c)

The effect on titanium dioxide retention obtained by flocculating pigmented systems at concentrated and dilute slurries was studied. Furnishes of 4.0 and 0.5% pulp consistencies were chosen for this study to represent two areas in a mill furnish where titanium dioxide might be introduced to the system and flocculated, i.e., at the beaters or near the headbox prior to going to the wire. The titanium dioxide (7% on the o.d. pulp) was flocculated with 2% alum on the o.d. pulp, both in the presence and absence of chlorinated starch. Since all additions were made at the same percentages on the o.d. pulp, the furnish at 4.0% consistency represents one in which the reactants were eight times more concentrated than that in the furnish at 0.5% pulp consistency. Thirty minutes agitation in the high-speed stock breaker was employed with all furnishes throughout this phase of the study. Handsheets were made at various time intervals, up to 5 hr. and titanium dioxide retention data were obtained by ashing (Table I and Fig. 1). The effect of concentration at flocculation was also investigated in the alum addition study (Tables II and IIa, Figs. 2, 2a, 2b, and 2c).

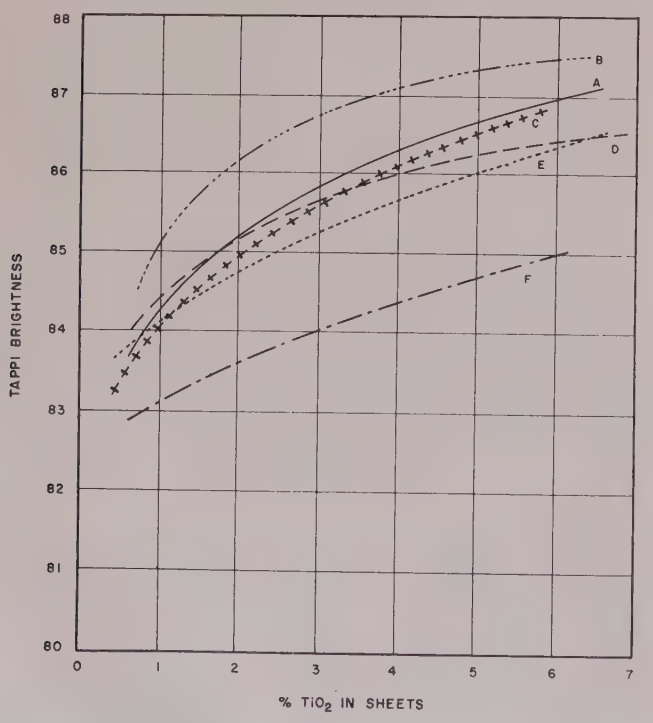

Fig. 5a. Effect of flocculation degree on optical efficiency of titanium dioxide

Effect of the Amount of Alum Addition (Tables II, IIa, and Figs. 2, 2a, 2b, 2c)

Variations in the amount of alum added to furnishes at 4 and 0.5% consistencies were investigated for the resultant effect on titanium dioxide retention and optical properties. The 7% titanium dioxide addition level was used throughout, both with and without chlorinated starch (2% on the o.d. pulp). Alum was added to the furnishes from a 4% solution to the various addition levels on the o.d. pulp. No agitation was performed after the alum was incorporated under low-speed paddle mixing. Flocculation was effected at the high (4%) and low (0.5%) concentration levels. pH readings were obtained with a Beckman pH meter on all furnishes after alum addition. Titanium dioxide retention data were again obtained by ashing the finished handsheets. Average TAPPI brightness values and TAPPI opacities, waxed and unwaxed, were also obtained from the sheets. Data from the furnishes flocculated at the 0.5% consistency level appear in Table II, and are plotted in Figs. 2 and 2a. Data obtained at the 4% consistency level appear in Table IIa and Figs. 2b and 2c.

Table VIII. Summary—Factors Which Influence Retention and Optical Efficiency

Variable	*Effect on agglomerate size of TiO_2* *No starch*	*With starch*
1. Increased agitation	Little effect	Decrease
2. Increased time	Increase	Decrease
3. Increased amount and/or concentration of:		
(a) Alum	Increase	Increase
(b) TiO_2	Increase	Increase
(c) Starch	. . .	Decrease

Effect of Agitation and Recovery Time (Table III, Fig. 3)

In this phase of the study, the effect on the pigment retention of agitating the flocculated titanium dioxide was observed. This investigation was carried out in the presence of 2% chlorinated starch on the pulp as well as without starch. The digestion or recovery cycle after agitation was also observed. The titanium dioxide addition was constant at 7%, and the pulp consistency was 0.5% at the time of flocculation by 2% alum addition. Agitation was accomplished by high-speed mixing in the stock breaker for a period of 30 min. after alum addition. Identical furnishes were also made with no agitation after flocculation for comparison at the various recovery time intervals, from 10 min. to 5 hr. Titanium dioxide retention data were obtained by ashing and plotted against recovery time (Table III and Fig. 3).

Effect of Clay Addition (Table IV)

Paper handsheets were made in this phase at 50-lb. basis weight with and without 2% chlorinated starch on the o.d. pulp at a constant level of titanium dioxide addition (7%), Filler clay addition varied from 0 to 200% on the o.d. pulp. The entire furnish was agitated in the stock breaker for 15 min. after flocculation with 2% alum on the o.d. pulp at 0.5% pulp consistency. The titanium dioxide content in the sheets was determined colorimetrically and the clay content was determined by ash difference, allowing for moisture loss on ignition of the clay. The per cent retention of these pigments was calculated, and waxed and unwaxed opacities were read (Table IV).

Effect of Water Dilution (Table V)

To study the effect on the flocculated titanium dioxide when diluted further with water, furnishes were made at 2, 7, and 15% titanium dioxide addition levels to the o.d. pulp. Flocculation was accomplished by the addition of 2% alum on the pulp at a pulp consistency of $^3/_4$%, both with and without 2% chlorinated starch on the pulp. The furnishes were agitated for 15 min. after flocculation with alum. Handsheets were made with this material at the $^3/_4$% consistency level at the wire. By successive dilutions of this furnish with distilled water, sheets were made at 0.5, 0.1, and 0.05% consistencies. Per cent retention of the titanium dioxide was calculated, and waxed opacities of the sheets were obtained (Table V). In the sheets made at the heavier consistencies, poor formation prevented obtaining meaningful opacity readings. It was not possible to make handsheeets from furnishes with consistencies above $^3/_4$%.

Effect of Temperature (Table VI, Fig. 4)

In order to observe the effect of temperature on flocculation of titanium dioxide and the resulting retention, it was necessary to deviate slightly from the normal laboratory method of making handsheets. In this portion of the study, the titanium dioxide was preflocculated by the addition of alum in a separate container from the pulp slurry. The concentrations and relative amounts of titanium dioxide, alum, and starch in water were chosen to represent those found in a furnish at 1% pulp consistency with an addition of 20% titanium dioxide on the o.d. pulp, and containing 2% alum and 3% starch on the dry pulp. The required amounts of pulp and distilled water were agitated on the stock breaker for 20 min. before further dilution in the proportioner so as to produce a final sheet weight of 25-lb. basis weight. The required volume of this slurry was added to the deckle box, to which a given volume of the preflocculated titanium dioxide slurry was added. Preflocculation of the titanium dioxide was carried out at 35, 77, and 190°F., and the slurries were held at these temperatures for 15 min. before handsheets were made. Titanium dioxide retention data and TAPPI opacity, waxed and unwaxed, are tabulated in Table VI and plotted in Fig. 4.

Effect of Flocculation Degree on Optical Efficiency of TiO_2 (Table VII, Figs. 5, 5a, and 5b)

In this phase of the study it was again necessary to deviate from the normal laboratory method of handsheet analysis. Titanium dioxide flocculates of increasing size were formed from dilute dispersions of titanium dioxide in distilled water by the addition of small quantities of alum and increasing amounts of a retention agent.* The range of flocculate size was observed by eye and under a microscope, and was found to increase directly with the increase in amount of alum and retention agent used. Portions of these slurries were added to dispersed pulp in the deckle box to yield 25-lb. basis weight sheets, with titanium dioxide contents ranging from 0 to 7% as determined by actual ashings. Average TAPPI brightness and opacity readings, waxed and unwaxed, were determined on these sheets and plotted against the actual titanium dioxide content in the paper to give families of curves with varying titanium dioxide flocculate size (Figs. 5, 5a, and 5b). For clarity, a few of the intermediate curves were eliminated. Data on these curves, however, appear with those plotted in Table VII.

* A sodium salt of acrylic acid, a type in general use in paper mills today.

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1. *Paper Trade J.* 102, No. 3: 36–39 (Jan. 16, 1936).
2. *Tappi* 38, No. 9: 522–526 (Sept., 1955).

Presented at the meeting of the Ohio Section of TAPPI, held in Middletown, Ohio, Dec. 8, 1959.

A Suggested Method for Reporting the Quality of Newsprint Paper

ALFRED S. TAYLOR

Since November, 1957, the American Newspaper Publishers Association Research Institute has been testing newsprint in an effort to isolate those physical properties that determine printing quality. This program was instituted by the publishers to learn more about their basic raw material—newsprint. To date, approximately 1200 rolls of newsprint have been tested. Samples from these rolls came from newspapers selected to give adequate mill coverage and a widespread geographic location. Initially, these samples were obtained from seven newspapers. At the present time, 79 newspapers are working with us.

The planning and instrumentation of this program began in May, 1957. From May until November we were testing instruments, installing air conditioning equipment, perfecting a sampling technique, adapting the IBM system to our data, selecting newspapers which would work with us, fitting their samples into a schedule, establishing our testing procedures, and taking care of the many details that precede such an extensive program.

The testing procedures that we follow are based, for the most part, on standard TAPPI Methods; and the instruments that we use are all commercially available. We have done this in order that the newsprint manufacturers may readily continue these studies of newsprint properties in their own plants. Our Laboratory is open on any working day and we have already had many visitors from the newsprint industry. We do not claim that this program is perfect; but, insofar as we know, it is the only one of its kind in operation today. We would like to improve it, and we welcome constructive criticism.

Alfred S. Taylor, ANPA Research Institute, Inc., Easton, Pa.

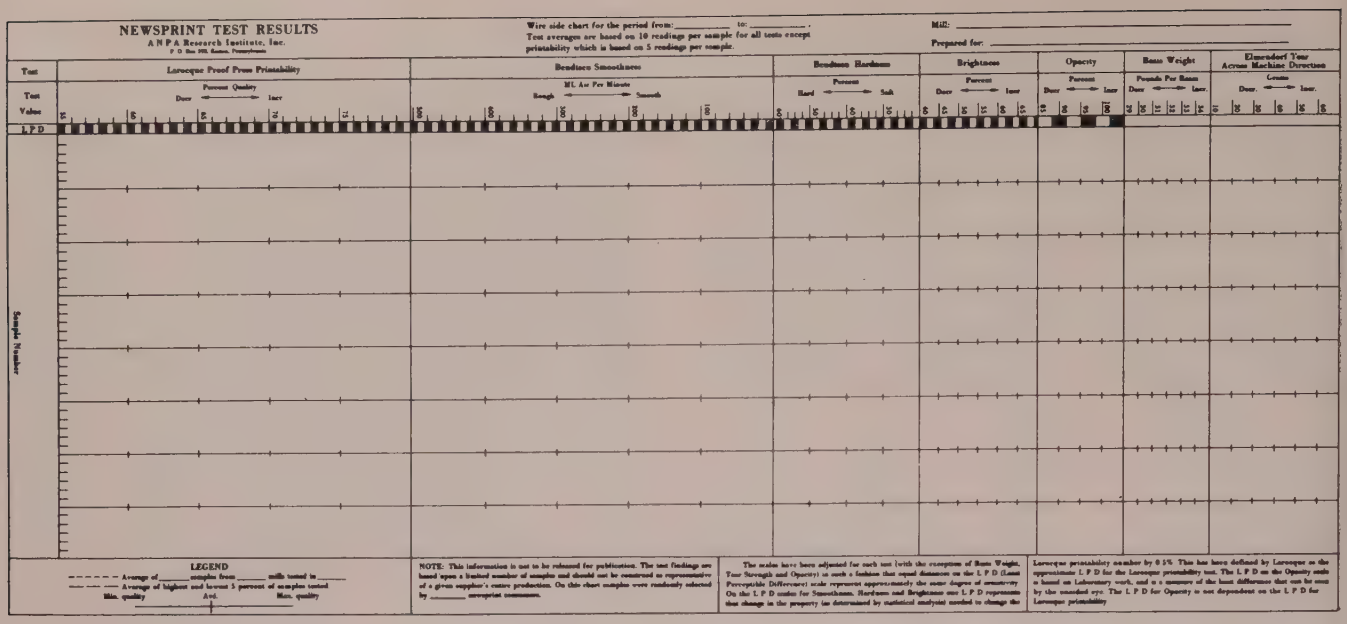
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from: _____ to: _____.
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample.
Mill: _____
Prepared for: _____
Test
Test Value
Lorocque Proof Press Printability
Percent Quality
Bendtsen Smoothness
Ml. Air Per Minute
Rough
Smooth
Bendtsen Hardness
Percent
Hard
Soft
Brightness
Opacity
Basis Weight
Pounds Per Basis
Elmendorf Tear Across Machine Direction
Grams
L P D
Sample Number
LEGEND
Average of _____ samples from _____ mills tested in _____.
Average of highest and lowest 5 percent of samples tested
Min. quality
Ave.
Max. quality
NOTE: This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire production. On this chart samples were randomly selected by _____ newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L P D (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L P D scales for Smoothness, Hardness and Brightness one L P D represents that change in the property (as determined by statistical analysis) needed to change the Lorocque printability number by 0.5. This has been defined by Lorocque as the approximate L P D for the Lorocque printability test. The L P D on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the standard eye. The L P D for Opacity is not dependent on the L P D for Lorocque printability

Fig. 1

The effect of smoothness, hardness, and brightness upon printing quality has been known for many years. Quite a few researchers have pointed out how these properties affect appearance of the printing. Our claim to uniqueness lies in the application of a statistical tool called "multiple regression analysis" and the fact that we have determined quantitatively, perhaps for the first time, the relative importance of these properties upon the printing quality of newsprint. Based on a study of 600 newsprint samples representing 53 manufacturers, the results show statistically that approximately 30% of the variation in printing quality as measured by the Larocque (*1*) proof press test is due to changes in smoothness, and 10% each, to changes in hardness and brightness. Details of our findings, including the correlation coefficients for different pairs of properties, selected scatter diagrams, description of the instruments, tests and test procedures and a summary of the statistical approach appear in the May, 1959, issue of *Tappi* (*2*).

Perhaps the most perplexing problem that we had to solve after getting the program into operation was that of reporting the data. One might suppose that it would be sufficient to report the measurements as we made them. However, let us consider what this would have meant. For most of the tests we made ten readings per roll. At one time we were making 25 different tests. Since we tested about 1200 rolls, we would be reporting 12,000 results per test, or about 300,000 observations in all. This would be ridiculous. We had to devise a more practical method of reporting our findings.

The method of reporting, therefore, had to meet certain criteria. These are:

1. It must present *useful data* only.
2. The data must be *complete.*
3. The data must be presented in small chunks for easy digestion.
4. Individual rolls must be *readily identifiable* to the newspapers that send them.
5. The format of the report must be of such a style that it can be *readily understood* by people with technical backgrounds as well as those with nontechnical backgrounds without oral instruction or briefing.
6. The format must lend itself easily to written explanation.
7. The method must permit easy up-dating.
8. Reference planes must be available for comparison.
9. And finally, the report must be of such an inconvenient size that it will not be easily lost in someone's filing cabinet. This is the only requirement that presented no problem.

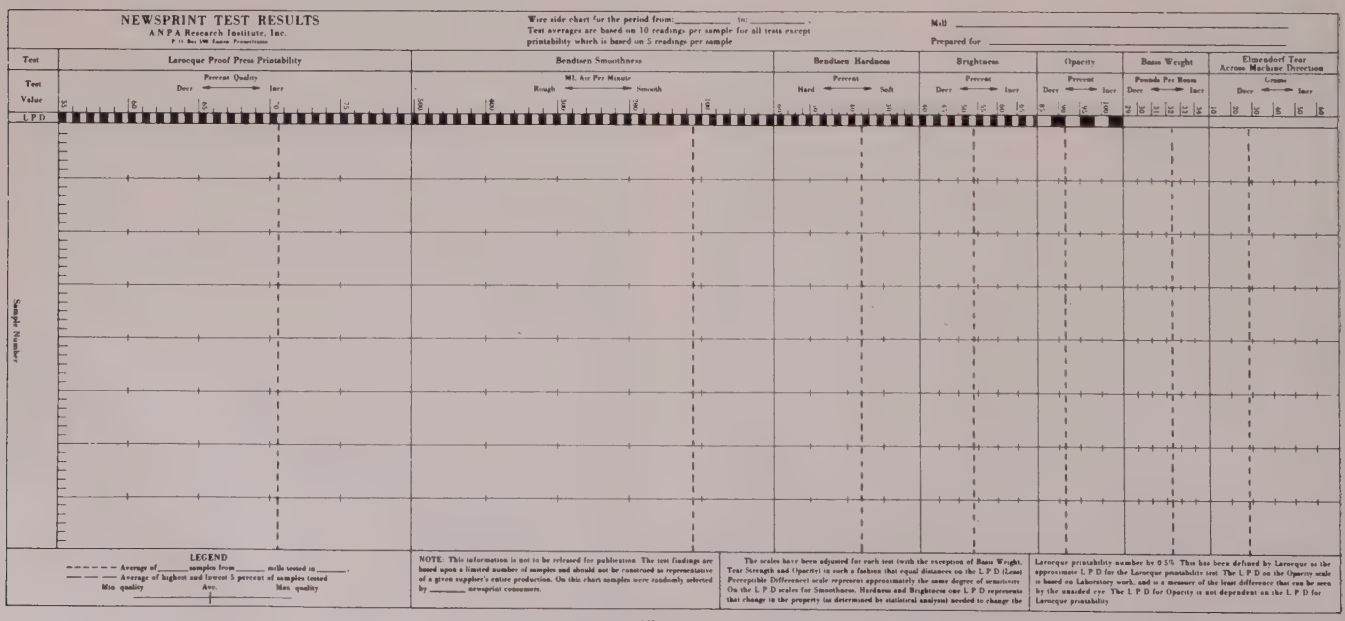
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from: _____ to: _____.
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample
Mill _____
Prepared for _____
Test
Test Value
Lorocque Proof Press Printability
Percent Quality
Bendtsen Smoothness
Ml. Air Per Minute
Rough
Smooth
Bendtsen Hardness
Percent
Hard
Soft
Brightness
Opacity
Basis Weight
Pounds Per Basis
Elmendorf Tear Across Machine Direction
Grams
L P D
Sample Number
LEGEND
Average of _____ samples from _____ mills tested in _____.
Average of highest and lowest 5 percent of samples tested
Min. quality
Ave.
Max. quality
NOTE: This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire production. On this chart samples were randomly selected by _____ newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L P D (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L P D scales for Smoothness, Hardness and Brightness one L P D represents that change in the property (as determined by statistical analysis) needed to change the Lorocque printability number by 0.5. This has been defined by Lorocque as the approximate L P D for the Lorocque printability test. The L P D on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the standard eye. The L P D for Opacity is not dependent on the L P D for Lorocque printability

Fig. 2

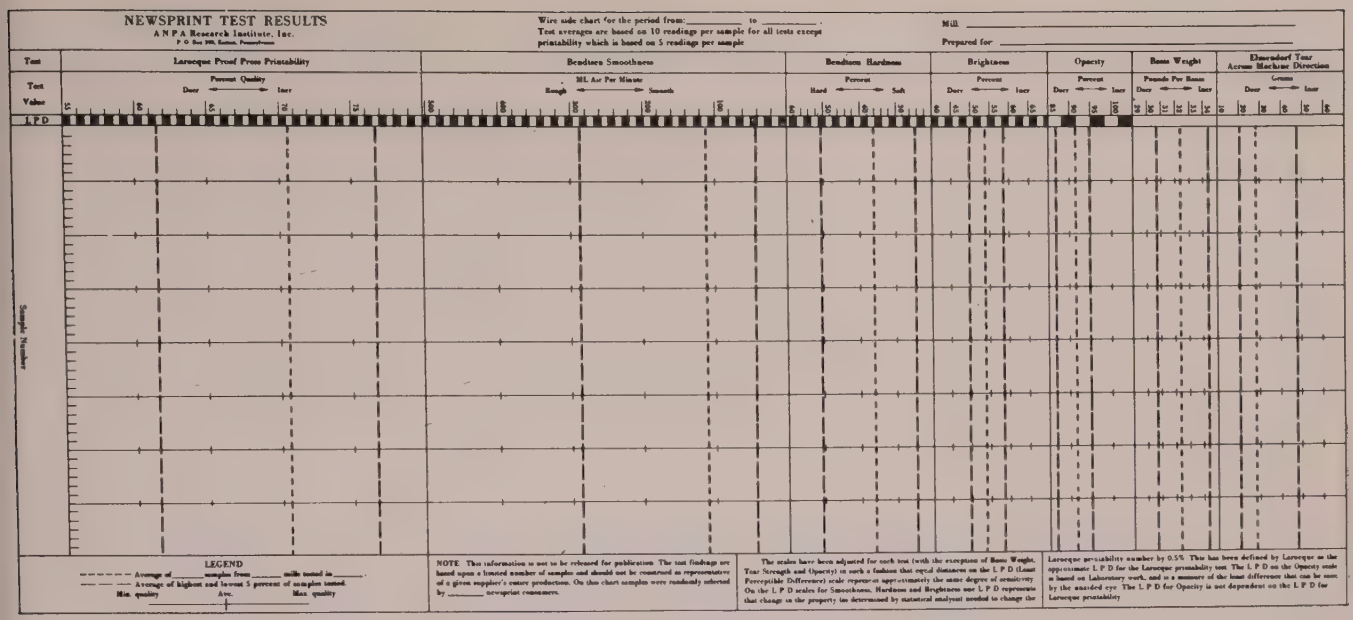
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from: _____ to _____.
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample
Mill _____
Prepared for _____
Test
Test Value
Larocque Proof Press Printability
Percent Quality
Dorr
Inor.
Bendtsen Smoothness
Ml. Air Per Minute
Rough
Smooth
Bendtsen Hardness
Percent
Hard
Soft
Brightness
Opacity
Basis Weight
Pounds Per Ream
Elmendorf Tear Across Machine Direction
Grams
L P D
Sample Number
LEGEND
Average of _____ samples from _____ mills tested is _____.
Average of highest and lowest 5 percent of samples tested.
Min. quality
Ave.
Max. quality
NOTE This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire productions. On this chart samples were randomly selected by _____ newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L P D (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L P D scales for Smoothness, Hardness and Brightness one L P D represents that change in the property (as determined by statistical analysis) needed to change the Larocque printability number by 0.5%. This has been defined by Larocque as the approximate L P D for the Larocque printability test. The L P D on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the unaided eye. The L P D for Opacity is not dependent on the L P D for Larocque printability

Fig. 3

The method of reporting is a graphical representation of selected test results by means of a device known as a varichart. This chart which we shall later on examine in detail is a simple way to present multiple test results so that they can easily be understood. (This is one of the criteria that the method of reporting had to satisfy.) For those who desire (or require) more information than is available from the chart, we can supply complete data sheets for each of the 1200 rolls tested. These data sheets, which are prepared on IBM machines, show the maximum, minimum, and average readings for every test made on a roll.

Figure 1 shows the chart as we print it. On the top we have spaces for the name of the mill, the name of the newspaper to which it was sent, the period covered by the samples, and the side of the paper for which results are shown. In the lower left-hand corner is given the number of samples used in calculating the average value for each property, the number of mills represented by these samples, and the year in which the samples were tested. At the bottom we also show the number of newspapers from which the samples were collected. For a given mill this may vary from one to six.

Down the left-hand side of the chart we place the test code, or sample number, assigned to the sample when it is opened for testing. This number identifies the sample. One chart represents all of the samples for a given newsprint mill as received from several newspapers. On the charts which we send to the newspapers working with us, we identify by means of a red check-mark the particular samples which were contributed by that newspaper. The test values that we show are Larocque proof press printability, Bendtsen smoothness, Bendtsen hardness, brightness, opacity, basis weight, and Elmendorf tear as measured across the machine direction.

Since the present phase of our program is concerned only with the printing quality of newsprint, we have placed printing quality first on the chart. Smoothness, hardness, and brightness follow since it has been shown by statistical analysis that they contribute significantly to printing quality. Opacity is shown primarily because of its effect upon showthrough. Basis weight is shown because of its economic importance. We show Elmendorf tear because of its possible relationship to pressroom performance.

For each of the properties shown except basis weight, improvements occur as the test values move to the right on the chart.

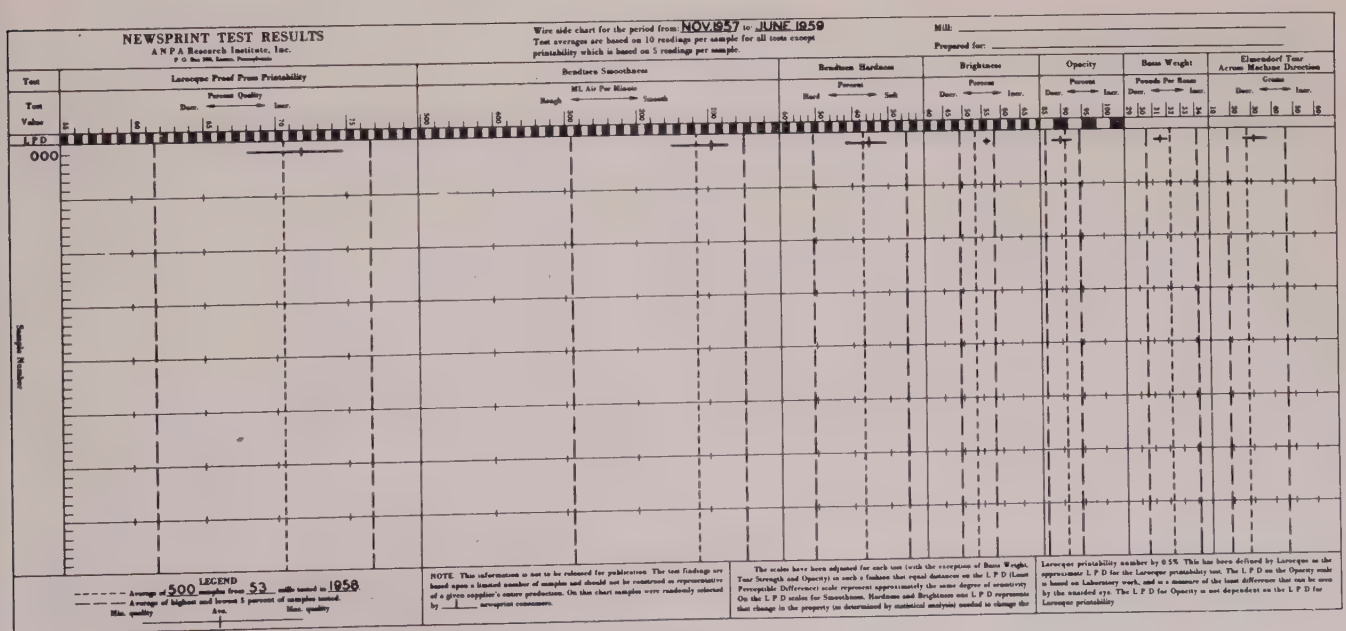
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from: NOV. 1957 to: JUNE 1958
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample.
Mill: _____
Prepared for: _____
Test
Test Value
Larocque Proof Press Printability
Percent Quality
Dorr
Inor.
Bendtsen Smoothness
Ml. Air Per Minute
Rough
Smooth
Bendtsen Hardness
Percent
Hard
Soft
Brightness
Opacity
Basis Weight
Pounds Per Ream
Elmendorf Tear Across Machine Direction
Grams
L P D
000
Sample Number
LEGEND
Average of 500 samples from 53 mills tested in 1958.
Average of highest and lowest 5 percent of samples tested.
Min. quality
Ave.
Max. quality
NOTE This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire productions. On this chart samples were randomly selected by _____ newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L P D (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L P D scales for Smoothness, Hardness and Brightness one L P D represents that change in the property (as determined by statistical analysis) needed to change the Larocque printability number by 0.5%. This has been defined by Larocque as the approximate L P D for the Larocque printability test. The L P D on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the unaided eye. The L P D for Opacity is not dependent on the L P D for Larocque printability

Fig. 4

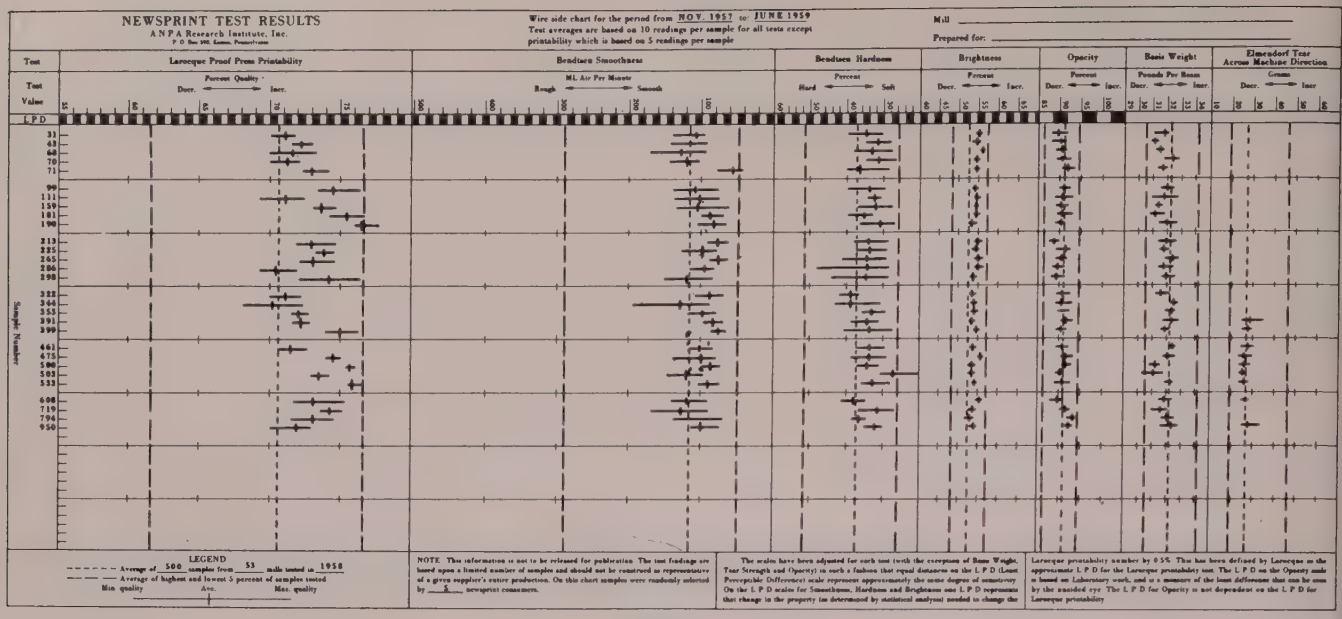
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from NOV. 1957 to JUNE 1959
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample
Mill
Prepared for:
Test
Larocque Proof Press Printability
Percent Quality
Decr. Incr.
Bendtsen Smoothness
ML Air Per Minute
Rough Smooth
Bendtsen Hardness
Percent
Hard Soft
Brightness
Percent
Opacity
Percent
Basis Weight
Pounds Per Ream
Elmendorf Tear Across Machine Direction
Grams
Test Value
LPD
Sample Number
LEGEND
Average of 500 samples from 53 mills tested in 1958
Average of highest and lowest 5 percent of samples tested
Min. quality
Ave.
Max. quality
NOTE. This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire production. On this chart samples were randomly selected by 5 newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L P D (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L P D scales for Smoothness, Hardness and Brightness one L P D represents that change in the property (as determined by statistical analysis) needed to change the Larocque printability number by 0.5%. This has been defined by Larocque as the approximate L P D for the Larocque printability test. The L P D on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the unaided eye. The L P D for Opacity is not dependent on the L P D for Larocque printability.

Fig. 5

There is one other part of the chart that needs explanation. The LPD or "Least Perceptible Difference" scale for each property shows the smallest incremental difference that is significant. In the case of the Larocque proof press test, the LPD has been defined by Larocque as approximately 0.5%. This is the smallest difference that can be visually observed. With respect to smoothness, hardness, and brightness, we define one LPD as that change in the property necessary to produce one LPD change in Larocque proof press printability. These values were obtained from a statistical analysis of the data. Unlike the previous properties, the LPD for opacity refers to the least difference which is visible to the unaided eye. It does not relate to Larocque printability.

A chart of this type is prepared for each newsprint mill for which we have ten or more samples. At the present time, we have such charts for 45 mills.

With this knowledge of the chart, let us look at Fig. 2. On this chart we have added, for each property, a line of short dashes at the numerical mean of 500 samples. These are the samples obtained from 53 mills tested in 1958.

In Fig. 3 we have added two lines of long dashes straddling the first line. The line to the right of the center line represents the best 5% and the line to the left, the poorest 5% of the samples for that particular property. These two lines do not represent statistical limits; they are merely the numerical mean of the best and poorest samples.

Now that we have an average line and lines representing the best and poorest samples, let us examine the findings for a given sample. In Fig. 4 the findings are represented by a horizontal "test line." This test line shows three different values of the results for each test. These are: the best (to the right), the poorest (to the left), and the average test value. The best is represented by the end of the line to the right; the poorest, by the end of the line to the left, and the average, by a short vertical dash through the test line. Note that to read this chart we read across in the horizontal direction.

The position of the test line with respect to the average of all 500 samples and with respect to the best and poorest 5%, makes it possible to compare any sample against all the others. The length of the line indicates the variability of the sample for this particular property.

Now that we have examined the construction of the chart, let us see what a few actual charts look like (Fig. 5). Let us

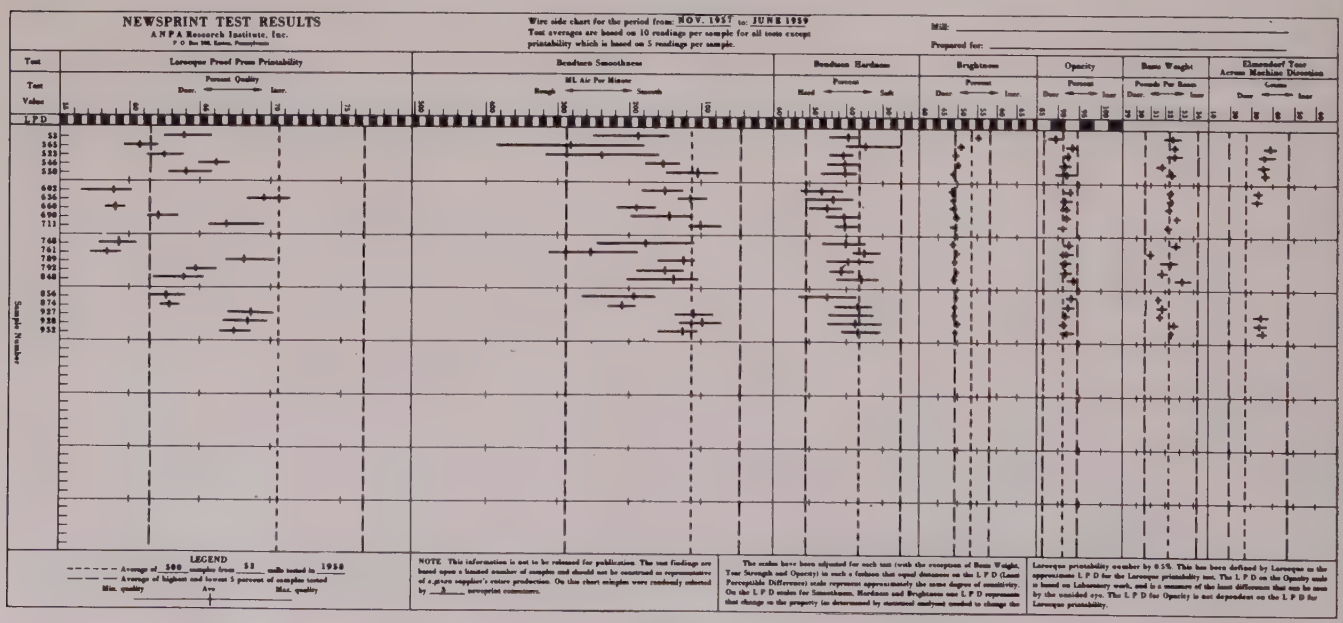
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from NOV. 1957 to JUNE 1959
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample.
Mill
Prepared for:
Larocque Proof Press Printability
Bendtsen Smoothness
Bendtsen Hardness
Brightness
Opacity
Basis Weight
Elmendorf Tear Across Machine Direction
LPD
Sample Number
LEGEND
Average of 500 samples from 53 mills tested in 1958
Average of highest and lowest 5 percent of samples tested
Min. quality
Ave.
Max. quality
NOTE. This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire production. On this chart samples were randomly selected by 5 newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L P D (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L P D scales for Smoothness, Hardness and Brightness one L P D represents that change in the property (as determined by statistical analysis) needed to change the Larocque printability number by 0.5%. This has been defined by Larocque as the approximate L P D for the Larocque printability test. The L P D on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the unaided eye. The L P D for Opacity is not dependent on the L P D for Larocque printability.

Fig. 6

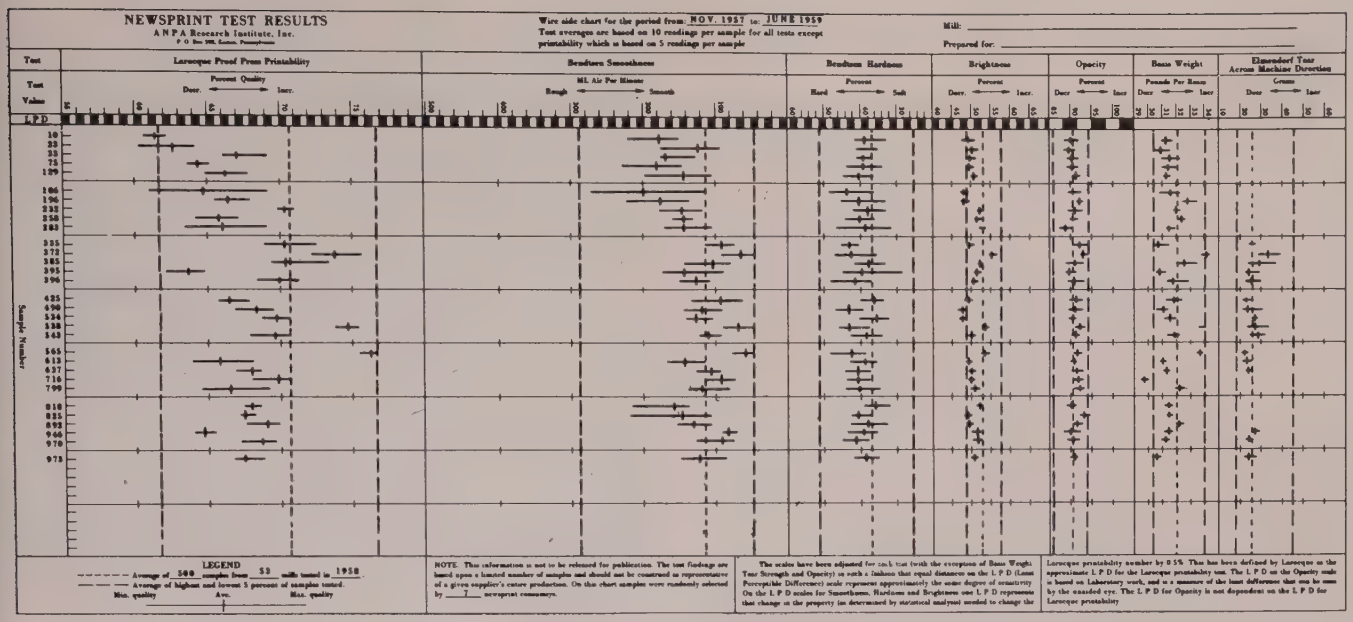
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from: NOV. 1957 to: JUNE 1959
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample
Mill:
Prepared for:
Test
Larocque Proof Press Printability
Bendtsen Smoothness
Bendtsen Hardness
Brightness
Opacity
Basis Weight
Elmendorf Tear Across Machine Direction
Test Value
Percent Quality
Doer.
Incr.
Ml. Air Per Minute
Rough
Smooth
Percent
Hard
Soft
Pounds Per Ream
Grams
L.P.D.
Sample Number
LEGEND
Average of 500 samples from 53 mills tested in 1958.
Average of highest and lowest 5 percent of samples tested.
Min. quality
Ave.
Max. quality
NOTE. This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire production. On this chart samples were randomly selected by 3 newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L.P.D. (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L.P.D. scales for Smoothness, Hardness and Brightness one L.P.D. represents that change in the property (as determined by statistical analysis) needed to change the Larocque printability number by 0.5%. This has been defined by Larocque as the approximate L.P.D. for the Larocque printability test. The L.P.D. on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the unaided eye. The L.P.D. for Opacity is not dependent on the L.P.D. for Larocque printability

Fig. 7

first examine the printability section. In the case of this supplier, note how most of the samples fall to the right, i.e., are better than the average line. Note also the change in position, with respect to the average line, from sample to sample. See how the length of the test lines change, indicating that certain samples are much more uniform than others. These samples were collected from five newspapers over 19 months, i.e., from November, 1957 to June, 1959.

In the section on smoothness, the same situation prevails. For the most part, the long test lines in the printability section are associated with long lines in the smoothness section, indicating the interrelationship of these two properties. There are some exceptions, which is only to be expected. Our statistical analysis tells us that the coefficient of correlation is about -0.7.

Looking at Bendtsen hardness and remembering that our correlation coefficient tells us that softer papers will yield better printing results, we are not surprised to find that most of the samples fall to the right, or on the soft side, of the average line.

For brightness the same situation prevails. Although the samples tend to cluster around the average line, they generally lie to the right or the brighter side.

Figure 6 is another actual chart. In this case, the pendulum has swung the other way. For printability, all of the samples lie to the left, or below the average line. Some of the samples test even poorer than the lowest 5% of the 500 samples. Variations from one sample to another are also quite pronounced. This can be expressed in terms of LPD's or least perceptible differences. There are 31 LPD's between the best and poorest samples on this chart. There were only 19 LPD'S between the best and poorest on the previous chart. Likewise, for smoothness, hardness and brightness, the test measurements lie generally to the left of, i.e., below the average line.

These charts cover a product known in the trade as "standard 32 lb. newsprint paper." Yet, there is an obvious and measurable difference between them. One has a tendency to be generally good, the other. . .?

In some cases, the samples from a given mill are neither consistently good nor poor, but vary widely in printability. The values obtained in Fig. 7 ranged from the very best to the

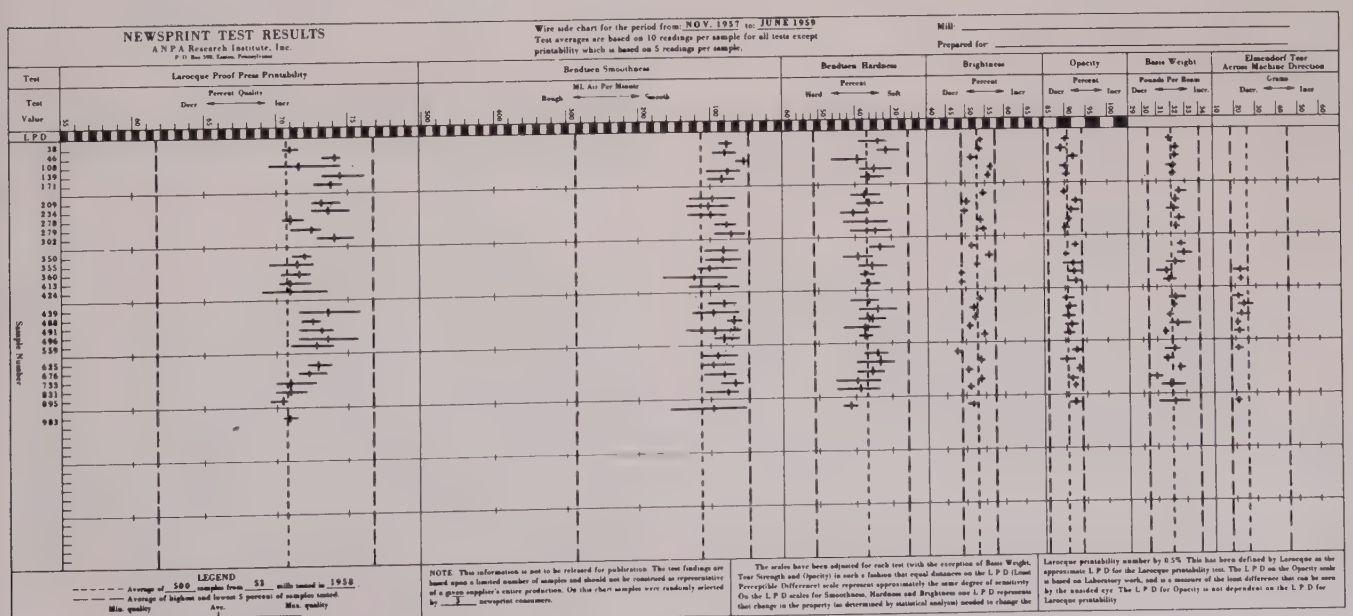
NEWSPRINT TEST RESULTS
ANPA Research Institute, Inc.
Wire side chart for the period from: NOV. 1957 to: JUNE 1959
Test averages are based on 10 readings per sample for all tests except printability which is based on 5 readings per sample.
Mill:
Prepared for:
Test
Larocque Proof Press Printability
Bendtsen Smoothness
Bendtsen Hardness
Brightness
Opacity
Basis Weight
Elmendorf Tear Across Machine Direction
Test Value
Percent Quality
Doer.
Incr.
Ml. Air Per Minute
Rough
Smooth
Percent
Hard
Soft
Pounds Per Ream
Grams
L.P.D.
Sample Number
LEGEND
Average of 500 samples from 53 mills tested in 1958.
Average of highest and lowest 5 percent of samples tested.
Min. quality
Ave.
Max. quality
NOTE. This information is not to be released for publication. The test findings are based upon a limited number of samples and should not be construed as representative of a given supplier's entire production. On this chart samples were randomly selected by 3 newsprint consumers.
The scales have been adjusted for each test (with the exception of Basis Weight, Tear Strength and Opacity) in such a fashion that equal distances on the L.P.D. (Least Perceptible Difference) scale represent approximately the same degree of sensitivity. On the L.P.D. scales for Smoothness, Hardness and Brightness one L.P.D. represents that change in the property (as determined by statistical analysis) needed to change the Larocque printability number by 0.5%. This has been defined by Larocque as the approximate L.P.D. for the Larocque printability test. The L.P.D. on the Opacity scale is based on Laboratory work, and is a measure of the least difference that can be seen by the unaided eye. The L.P.D. for Opacity is not dependent on the L.P.D. for Larocque printability

Fig. 8

Mill Code	News Code	Print. Pref. A	Print. Pref. R	Test Code	Test No.	Average	Minimum	Maximum
9	39	3	1	0671	1	6 26	6 24	6 30
					2	31 03	30 30	31 80
					3	3 12	3 00	3 20
					4	94 10	82 00	108 00
					5	93 60	78 00	107 00
					6	121 30	103 00	147 00
					7	36 90	29 90	41 20
					8	35 62	29 20	43 70
					9	251 00	177 00	355 00
					10	70 08	69 30	71 40
					11	70 86	70 50	71 50
					16	88 81	87 50	90 50
					17	95 97	95 48	96 86
					18	55 57	55 20	55 90
					19	99 46	99 46	99 46
					22	33 03	27 00	39 20
					23	40 29	31 10	47 50
					24	53 16	51 60	54 70
					25	54 22	54 00	54 50

Fig. 9

poorest in printability. This is the widest range of quality which we have encountered and represents 34 LPD's of printability. Again, all of these samples were purchased as "standard newsprint."

Figure 8 is the last chart we shall examine. This mill is among the best. The printability generally lies well above the mean. The smoothness is uniform—a factor of considerable importance from a pressroom operating standpoint, since it permits a more level ink setting (and better reproduction) throughout an edition. Of interest are the pronounced variations in brightness which tie in with similar variations in opacity, i.e., the brighter samples tend to be less opaque.

Figure 9 shows one of our IBM data sheets. It gives all the test results for one sample from a single roll of newsprint and contains the following information.

1. Our code number for the mill.
2. Our code number for the newspaper.
3. Quality rating by newspaper.
4. The sample number which we call Test Code.
5. The identifying number for each individual test. This we call Test Number.
6. Average reading.
7. Minimum reading.
8. Maximum reading.
9. Date printed at newspaper.
10. Roll number.

Items 9 and 10 are not shown in Fig. 9. They are, however, now being placed on the IBM data sheets. These sheets are available at our cost to any mill requesting them. The cost is 25¢ per set of duplicate sheets.

The current emphasis on proof press printing, smoothness, hardness, and opacity for the numerical evaluation of newsprint quality and the foregoing charts as a suggested method of reporting printing quality, raises the broader question about the purpose of such tests and the role which quality evaluation plays in the progress of any industry.

Let us go back to December, 1936, and hear what the late Christian Bendtsen, (*3*) a pioneer of newsprint testing, had to say on this subject.

"The absence of a clear definition of newsprint quality has undoubtedly been felt equally keenly by manufacturer and consumer alike. Everyone who has had to do with the buying or selling, production or consumption of newsprint knows the disconcerting feeling that seizes one when facing certain complaints and difficulties, the real nature of which is as obscure as the actual causes often appear difficult to ascertain."

Mr. Bendtsen went on to say,

"By the term, 'definition,' relative to newsprint quality is not meant a mere verbal description, such as I must perforce give you today, nor, still less, a description framed in sentimental subjective phrases. In this as in other cases of quality description, it would be desirable if the various properties that newsprint should possess could be formulated in an exact technical terminology, and, moreover, that a system of figures be devised whereby these properties could be expressed in a simple and easily reproducible manner."

To this I would only add that the improvement of printing quality would seem to be a mutual problem for the mill and newspaper. Newspapers face today competition from a powerful new medium which did not exist in 1936. This (and other forms of competition) has reduced the newspapers' share of total advertising from 45% in 1935 to 30.6% in 1959. The trend may well continue. This is the reason why newspapers need clean, crisp printing, and illustrations which are attractive to the advertiser and to the reader. If we are to stem the drift of advertising to other forms of communication, we must have better printing. If we are to have this better printing, the mills and the newspapers must work together.

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2. Prince, R. W., *Tappi* 42, No. 5: 418–424 (May, 1959).
3. Bendtsen, C., "Newsprint Regarded from the Buyer's Point of View," published by The Joint-Purchasing Association of the Danish Press, Copenhagen, January, 1937.

Received Aug. 11, 1959. Presented at the 10th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Portland, Ore., Aug. 17–21, 1959.

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Experiences with a Small Conical Refiner

JAMES L. McANDIE

In December, 1958, the 200 h.p. no. 6 "stock-maker" in the Morden Machines Co. stock preparation pilot plant was replaced by a new size and model stock-maker, the 60 h.p. no. 2.5 "HD." This smaller conical refiner was especially designed for pilot plant and small commercial installations. Although it embodied several design improvements, the refining principle remained identical to that of the no. 6 stock-maker (see Fig. 1).

This principle is based upon the unique "reverse-flow" feature of the stock-maker. Stock is pumped into the inlet chamber where it enters the inside of the hollow rotor. The rotor pumping vanes increase the pressure by approximately 30 p.s.i. at the large end of the rotor. Here the stock enters the treatment zone and flows between the refining elements to the small end of the rotor. The normal pumping action of the rotor filling bars causes a pressure of approximately 25 p.s.i. against the flow of stock. The stock then leaves the outlet chamber of the refiner at a pressure of 5 p.s.i. higher than the inlet pressure. The opposing internal-flow pressures constantly hold a full cushion of stock between the rotor and shell bars, thus minimizing the possibility of fiber abuse.

The pilot stock-maker has opened up new horizons for refiner testing in our laboratory: (1) the smaller stock flow requirements allow much greater hydraulic variations with existing pumping and storage capacity, (2) the ease of rotor and shell removal make possible frequent inspections of bar conditions and the greater economy of manufacture of the smaller filling elements permits the evaluation of many ex-

James L. McAndie, Development Engineer, Morden Machines Co., Portland, Ore.

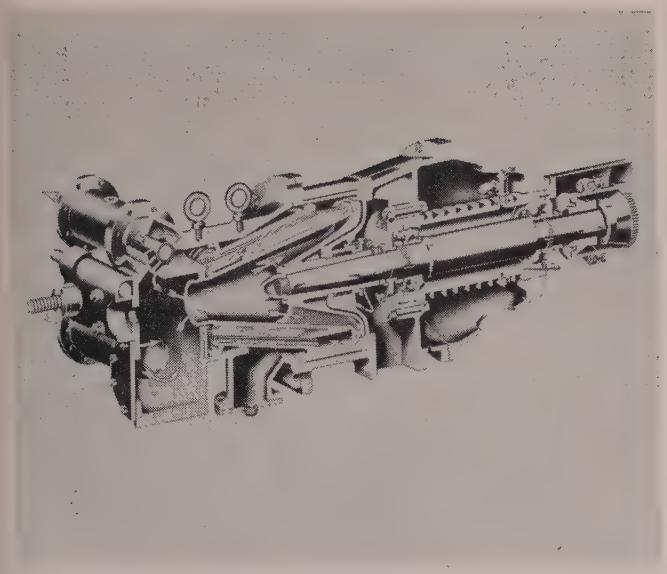

Fig. 1. Morden "Stock-Maker" Model "HA"

perimental filling designs, (3) a V-belt drive permits the study of a variation in rotor speeds.

Following installation and break-in of a set of standard bronze fillings ($^3/_8$-in. wide bars), a testing program was launched to determine the effects of the physical variables which may affect any refiner installation.

MORDEN PILOT PLANT OPERATION

Discussion of the results of this testing program should be preceded by a brief discussion of the operation of the refiner (Fig. 2).

The pulp, a western Canadian bleached kraft throughout this phase of the program, was repulped in the pilot "slush-maker." After complete defibering, the stock was pumped through the refiner and returned to the slush-maker tank. The throttling valves were adjusted to provide the desired flow and pressure conditions, the refiner shell was set up on the rotor to the desired initial power setting, and timing of the test was started. Samples of the refined stock were taken at given time intervals, and the test continued until a freeness level of 100 cc. or less was achieved, wherever possible.

Evaluation of Results

Testing Methods.—All testing was done on basis of TAPPI Standards; physical testing as outlined in TAPPI Standard T 220 m-53 (Physical Testing of Pulp Handsheets), and Canadian Standard freeness testing as outlined in TAPPI Standard T 227 m-50 (Pulp Freeness). Terms are defined as follows:

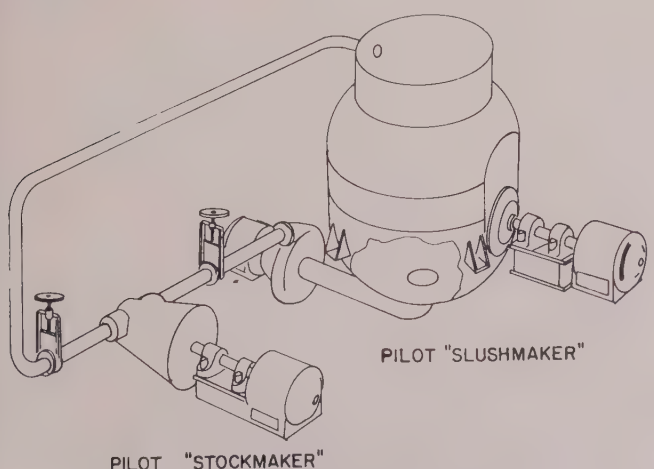

Fig. 2. Morden stock preparation pilot plant

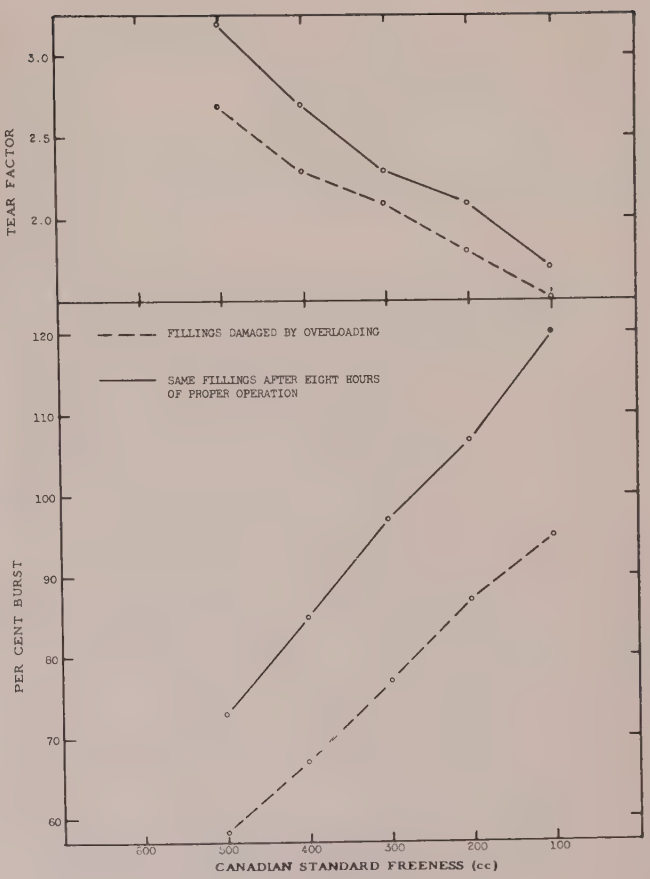

Fig. 3. Effect of bar condition

Basis Weight: Pounds per 500 sheets, 25 × 40 in. (moisture-free basis).

Per Cent Burst (Mullen): Obtained by dividing the bursting strength times 100 by the basis weight, where bursting strength is expressed in pounds per square inch.

Tear Factor: Obtained by dividing tear resistance by the basis weight, where the tear resistance is defined as the force in grams to tear a single sheet.

Testing Evaluation.—Freeness, burst, and tear data were plotted against time, then burst and tear values at given freeness levels were determined for comparative study. It should be noted at this point that the glaring weaknesses in the freeness test, as such, are readily admitted—particularly its inability to differentiate between brushing and cutting and/or degree of each attained in a sample. It was felt that, in spite of the above shortcomings, definite and reasonably

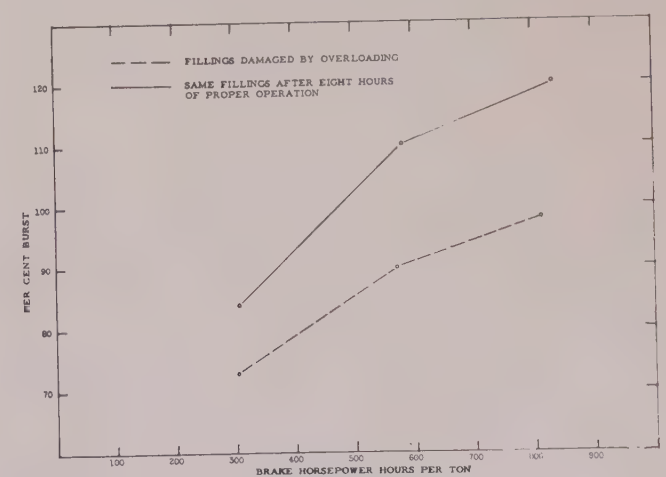

Fig. 4. Effect of bar condition

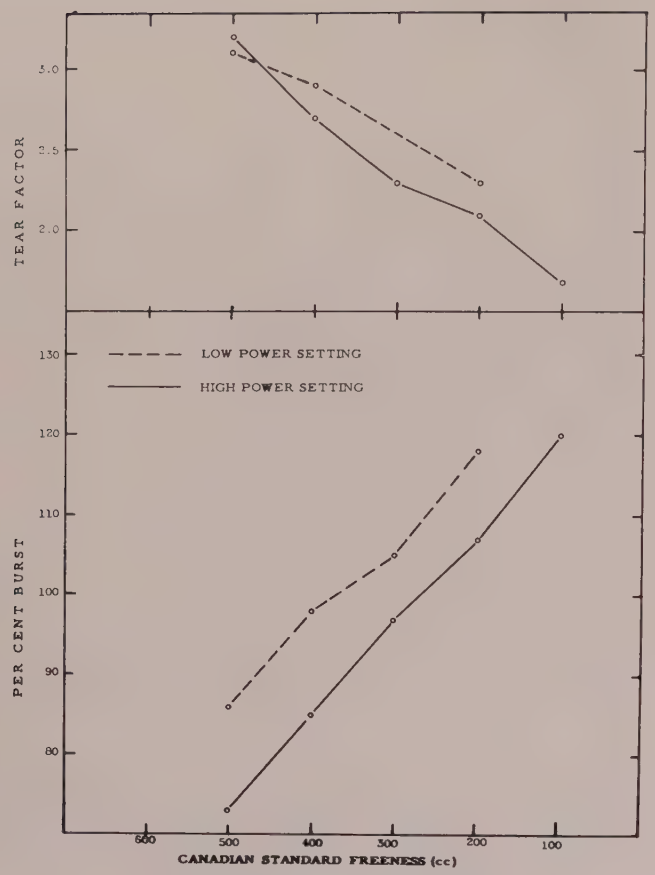

Fig. 5. Effect of power setting

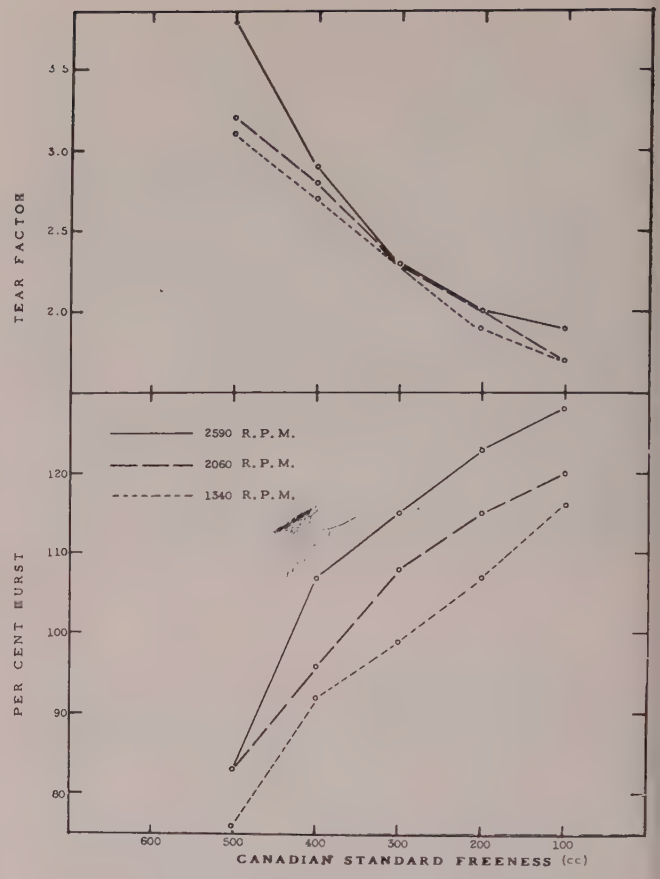

Fig. 7. Effect of rotor speed

accurate trends could be established for a given type of pulp and refiner tackle. In order to maintain a close check on freeness-based results, microscopic study was used, and more recently, a fiber classifier was put into use.

In order to further broaden the base of comparison, consumed power, expressed in horsepower-hours per ton, was plotted against per cent burst as well as against Canadian Standard freeness.

DISCUSSION OF RESULTS

Variables studied which showed a significant effect on the results of refining were: (1) condition of filling bars, (2) power setting—bar pressure, (3) rotor speed, and (4) consistency.

Condition of Filling Bars

This was found to be the most important single factor in terms of the physical results attained during the refiner run. The fillings were severely overloaded for several hours. The bars, which normally had slight trailing edge burrs and dull leading edges, were found after this run to have developed extremely sharp trailing edge burrs and fairly sharp leading edge burrs.

A standard test was then run, followed by a total of 8 hr. of normal operation, then a second standard test. After this second test, the bars were found to have returned to a normal condition.

The results from these two tests are shown in Figs. 3 and 4. The excessively sharp bars caused a 20% drop in per cent burst, 11 to 15% drop in tear factor and a 55 to 62% increase in horsepower-hours per ton to an equal burst value in the range where comparison may be made.

Power Setting (bar pressure)

Two initial power settings were used—40 and 50 h.p. (Figs. 5 and 6). Forty horsepower was found to be the lowest

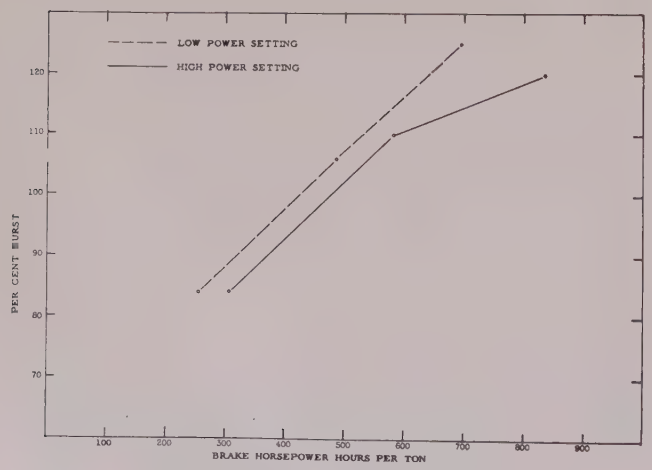

Fig. 6. Effect of power setting

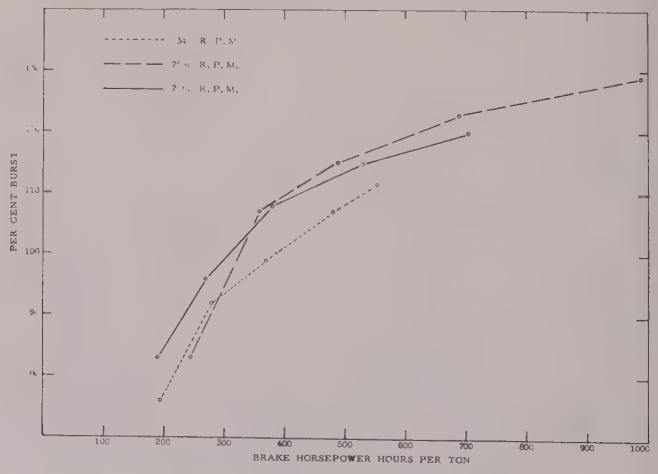

Fig. 8. Effect of rotor speed

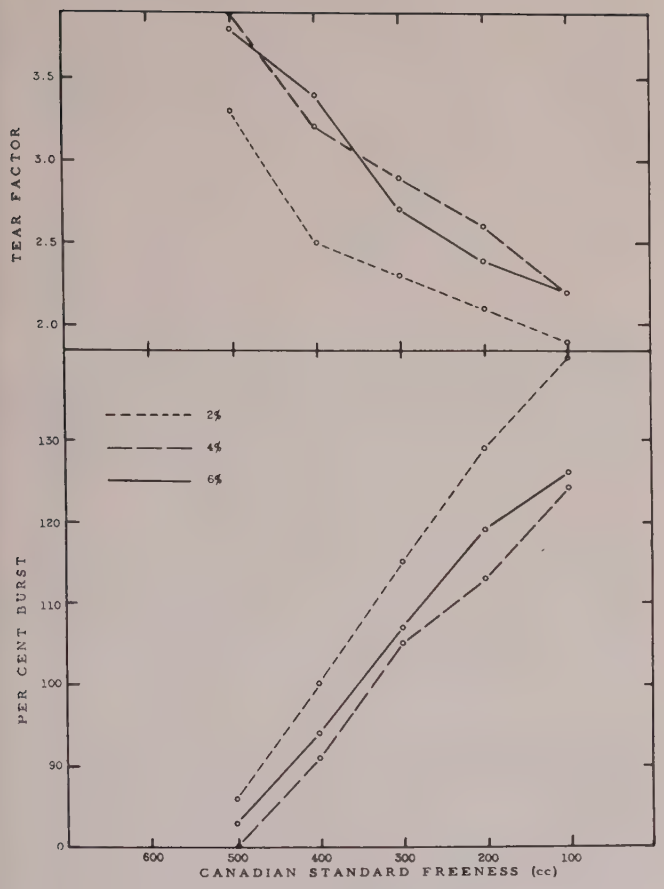

Fig. 9. Effect of consistency

setting practical in obtaining results within a reasonable length of time, and 50 h.p. proved to be fairly close to the maximum allowable before the bars would break through the fiber film and run metal to metal.

The lower power setting produced 10 to 18% higher burst and, generally, about 10% higher tear factor. The lower power setting also required from 8 to 20% less horsepower-hours per ton to reach a given burst value.

Rotor Speed

Speeds of 1340, 2060, and 2590 r.p.m. were run at power settings which gave an equal net average applied horsepower. The 2060-rate is the equivalent of 900 r.p.m. in a no. 6, 150 hp., stock-maker and is considered the standard operating speed.

The high speed resulted in appreciably higher burst and slightly higher tear than the standard, while the low speed produced an opposite trend (see Fig. 7).

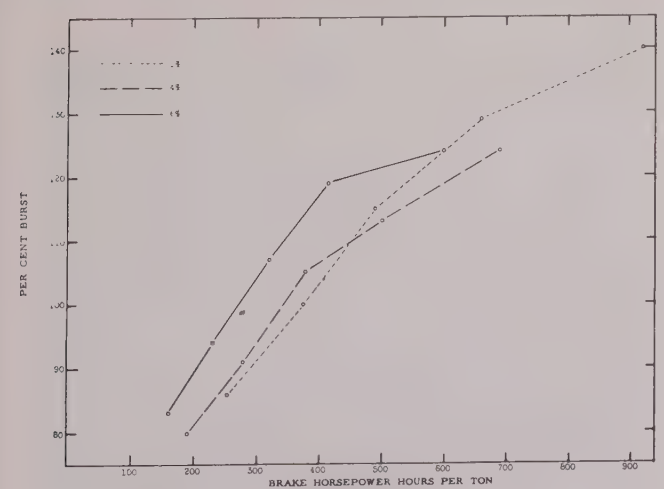

Fig. 10

The low speed tests required considerably more horsepower-hours per ton to a given burst level than did the standard test. The high speed tests also required more horsepower-hours per ton than the standard. The no-load power consumption of the high speed tests was extremely high and consequently counteracted the superior burst development noted (see Fig. 8).

Consistency

Two, four, and six per cent airdry consistencies were tested. Little difference was noted between 4 and 6% as far as burst and tear are concerned; but 2% showed considerably higher burst and lower tear factor (Fig. 9).

Little difference in efficiency was noted between 2 and 4% with 6% requiring considerably less power to reach a given burst level, up to a value of 120 (Fig. 10).

SUMMARY

It has been established that, other factors being equal, tackle condition can have a tremendous effect on results of refining. The critical nature of this condition is emphasized by the fact that the fillings used in the small refiner, when at their worst condition as far as results were concerned, appeared to be in *much* better condition than many of the commercially used fillings which have been inspected. It has also been established that refiner power setting has a considerable effect on physical results of the refining—especially when the maximum load-carrying ability of the pulp is reached, and that, to a considerably less degree, stock consistency and rotor speed have an effect on refiner results.

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Lateral Forces on Pulp & Paper Mill Structures

JOHN H. BRINGHURST, JR.

The purpose of this paper is to discuss the probable lateral forces that pulp and paper mill structures may have to carry. Lateral forces, unlike vertical loads, or weights, are not readily apparent and in many instances are of infrequent application. Structures must, however, be designed to resist or carry such forces when they do occur, as these forces are just as "real" as applied vertical loads. Lack of provision in structural design to carry such forces may lead to excessive deflection and distortion of a structure or structural member, to objectionable vibration and movement, and even to structural collapse.

WIND FORCES

Perhaps the most universally recognized and least understood lateral force is the force due to wind pressure. The effect of wind forces on the sizing of the individual members in a structure is probably not realized by any but the structural engineer or others who have been closely associated with the structural design of a mill. As size of structural element and cost are directly proportional, it is important that management officials have an understanding of this important force and its effect on building frame costs.

Two basic cyclonic effects produce wind forces. The most violent and the most concentrated of these is the tornado, which generates wind velocities well above the measuring

John H. Bringhurst, Jr., Vice-President, J. E. Sirrine Co., Greenville, S. C.

capacity of weather instruments. The force of these velocities (possibly approaching 500 m.p.h.) is of such extremely high magnitude that it is practically impossible to design structures throughout a plant strong enough to withstand tornadoes. This should not be construed to mean that in areas subject to tornadic winds all lateral wind forces should be neglected, and a zero wind force design used. Provision for a reasonable wind force may mean the difference between minor loss and major damage in event of a near-miss by a tornado. Recognizing this possibility, and its effect on saving of human life, building code authorities provide for a minimum wind force which must be used in structural design.

Hurricanes are the second important cyclonic effect which produce large wind forces. These storms cover extremely wide areas with wind velocities up to 140 or 150 m.p.h. They are extremely devastating in our coastal areas, and in recent years seem to be changing their traditional patterns and visiting inland locations heretofore free from these storms. As violent as these winds may be, they are still within the range of economical structural design to carry their lateral pressure forces. Gales and lesser winds, of course, fall in this range, also.

Much thought has been given by many engineers, insurance companies, building code authorities, and governmental agencies to the force of winds on buildings and structures. A digest of some of these is contained in Appendix A and B. From these it will be noted that there exists a lack of uniformity in converting from wind velocity to wind pressure as well as lack of uniformity between various building-code authorities as to minimum design wind pressures.

There does exist reasonably close agreement between the American Standards Association's, the Bureau of Yards and Docks' and Dryden and Hill's pressure velocity formulas. The writer recommends that either of these be used. For the normal height range of paper mill structures, the Dryden and Hill formula

$$P = 0.00256V^2$$

is simple to use and is probably well within the accuracy of either record wind velocities or assumed wind velocities. Weather Bureau velocities, giving the greatest 5-min. average speed, should be multiplied by a gust factor of 1.5 "to account for gust speeds that are not picked up as a direct reading on the recording instrument."[1] This gust factor is extremely important *and very easily overlooked.*

Design wind forces must also comply with the legal requirements of minimum wind pressures contained in controlling building codes. These should be consulted. Almost all codes also state that "no allowance shall be made for shielding effect of other buildings."[2]

Having considered briefly this matter of wind pressure force on structures, the following tabulation, taken from similar actual structures designed for different wind forces, will give an indication of the effect that this force may have on building frame costs.

For bleach plant "B," with a volume of approximately 650,000 cu. ft. this makes a difference in frame cost of about $26,000, depending on the plant location between an area where winds of 88 m.p.h.[3] maximum gust velocity and 108 m.p.h.[4] maximum gust velocity may be expected.

If this is extended to a one-machine pulp and paper mill with a total volume of buildings of 9,000,000 cu. ft., and if the unit frame cost difference is presumed to be $0.02 per cu. ft. (as many structures are not so tall as a bleach plant), this could make a dollar difference in structual cost of $180,000. With such possible economic differences as this, the required

Building	*Size*	*Wind load, lb./sq. ft.*	*Str. steel, lb./cu. ft.*	*Str. steel cost, $/cu. ft. @ 850/ton*
Bleach plant "A"	141.5 × 62 × 91.5 high	20	1.26	0.22
Bleach plant "B"	112 × 62 × 94 ft. high	30	1.50	0.26
			Difference	=0.04/cu. ft.

wind pressure for design purposes becomes of immediate importance. Briefly, underdesign in wind load may endanger continued production and hence could prove very costly, while overdesign will waste money in unneeded strength.

EARTHQUAKE FORCES

The next major possible lateral force on mill structures, and one that in certain geographical areas may exceed wind force, is the seismic force produced by earthquakes. No attempt will be made here to go into the complexities of earthquake design, but this possible lateral force may affect structural costs substantially, when proper provision is made. Conversely, lack of proper structural provision for earthquake forces may permit huge losses of money, and loss of life, in event of a major seismic disturbance. This all resolves itself to a matter of geography and history of past earth movements with their resulting shocks. It might be mentioned that proper provision for wind forces increases a structure's ability to withstand earthquake forces.

At the mention of earthquakes, and the need for earthquake design, the natural inclination is to think of California, and of San Francisco in particular. The fact that other equally as destructive earthquakes have occurred in the central part of the United States, and on the east coast, is easily overlooked in developing basic design criteria. Mexico and Canada also have suffered disastrous and strong earth shocks. Two easily referenced maps showing seismic probability are the Seismic Probability Map of the United States prepared by the U. S. Coast and Geodetic Survey and published in the Uniform Building Code (Fig. 1), and the Earthquake Zones of Seismic Probability for Continental United States (Fig. 2), contained in the Bureau of Yards and Docks Technical Publication NavDocks, TP-Te-3. A brief and comprehensive résumé of earthquake history in the United States is contained in the U. S. Department of Commerce Special Publication No. 282, "Earthquake investigation in the United States."

Building codes in certain areas, particularly on the west coast, require earthquake design. A review of the maps

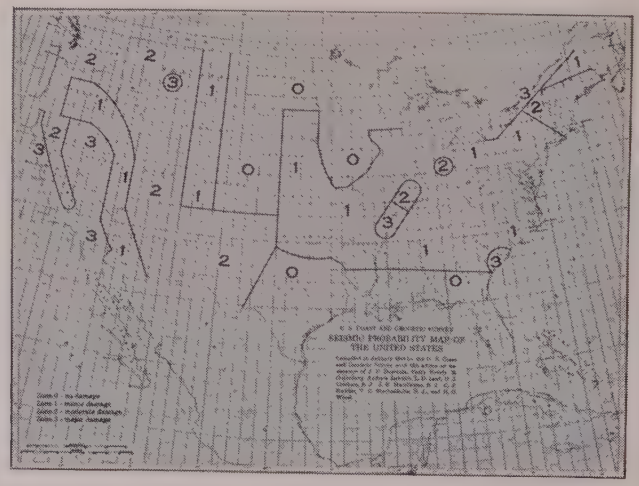

Fig. 1. Seismic probability map of the United States

[1] New Standard Wind Load Requirements, J. P. Thompson, *Eng. News Record*, p. 34 (Feb. 14, 1957).
[2] National Building Code, p. 111 (1955).
[3-4] Based on Dryden & Hill $P = 0.00256V^2$. Note that maximum gust may be 1.5 times the maximum average 5-min. velocity recorded by the Weather Bureau.

and references above may indicate the desirability of such, even if not required by law. In this connection, e.g., a major earthquake occurred at Charleston, S. C., in 1886, with 60 lives lost. Reports of this shock indicate that it approached the 1906 San Francisco earthquake in intensity. The Charleston area is rated as a high seismic probability on both of the above mentioned maps.

MISCELLANEOUS FORCES

Other lateral forces which may affect pulp and paper mill structures are listed below:

1. Pipe thrusts due to pressure and water hammer. Those due to bellows-type expansion joints in relatively high pressure steam lines may be deceptive in their magnitude. For example, a 20-in. diameter steam line carrying 600 p.s.i. pressure, with this type of joint, can exert a force of almost 190,000 lb.; and water-hammer forces in large pipe lines should always be investigated.
2. Thermal forces due to high temperature equipment, etc. The best approach is to provide for expansion movement and not to restrain such forces. Restrained, either intentionally or by accident, these forces may prove of such magnitude that they cannot be resisted, with resultant distortion or cracking.
3. Earth pressures on retaining and foundation walls.

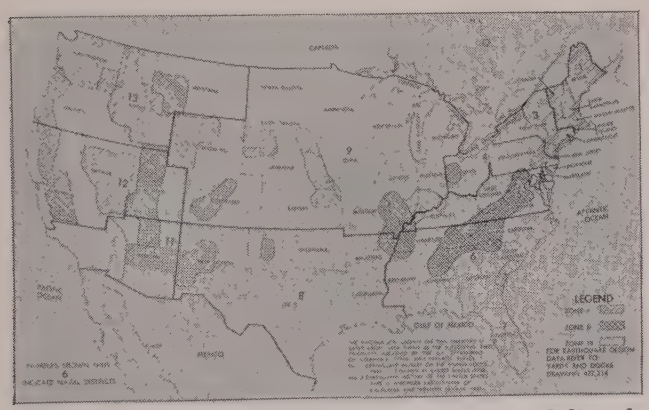

Fig. 2. Earthquake zones of seismic probability for continental United States

4. Hydrostatic forces in tanks and chests.
5. Crane lateral and longitudinal forces and other dynamic equipment forces.

These last lateral forces might be considered as minor because they will not affect the entire plant, but only certain areas, members or foundations. To overlook them, however, is to invite structural difficulties and possibly failures, leading to property damage and loss of production. Although minor by comparison (because they are localized), they warrant mention to completely cover the field of lateral forces that may have to be carried by pulp and paper mill structures.

APPENDIX A
WIND FORCE FORMULAS

Struct. Engineers' Handbook: $P = 0.004V^2$
P = lb. per sq. ft. on a flat surface normal to direction of wind
V = velocity in m.p.h.

U. S. Weather Bureau (old formula): $P = 0.0033V^2$ with same units.

Dryden and Hill: $P = 0.00256V^2$ with same units.

Bureau of Yards and Docks[5]: $P_{30} = 0.00256V^2$ at height 30 ft. above ground
P increased by a coefficient (>1) depending on height above 50 ft.

National Bureau of Standards[6]: $P_{30} = 0.01486\left(\frac{V_h}{\sqrt[7]{h}}\right)^2$ with same units
h = height in ft. at which V_h is measured.

American Standards Assoc.[7]: $P = 0.00258V^2\left(\frac{h}{30}\right)^{2/7}$

APPENDIX B
MINIMUM WIND CRITERIA

Associated Factory Mutual Fire Insurance Co. Bulletin No. 7.13, p. 2: "Walls and window supports need to resist a total horizontal (wind) force of 27 lb. per sq. ft."

BuY&D[8]: "In no case shall a structure be designed for a wind velocity of less than 70 m.p.h."

Factory Insurance Assoc.: "New construction should be designed to withstand wind velocity of not less than 100 m.p.h...."

Southeastern Underwriter's Building Code (1952): 20 lb. per sq. ft.

New Orleans, La., Code (1952): less than 60 ft.—20 lb. per sq. ft.; over 60 ft.—30 lb. per sq. ft.

Houston, Tex., Code (1952): less than 50 ft.—25 lb. per sq. ft.; 50 to 99 ft.—30 lb. per sq. ft.; 100 to 199 ft.—35 lb. per sq. ft.

National Building Code (1955): less than 30 ft.—15 lb. per sq. ft.; 30 to 49 ft.—20 lb. per sq. ft.; 50 to 99 ft.—25 lb. per sq. ft.; 100 to 499 ft.—30 lb. per sq. ft.

Uniform Building Code (1949): less than 60 ft.—15 lb. per sq. ft. min.; over 60 ft.—20 lb. per sq. ft. min.

		Inland, lb. per sq. ft.	*Coastal, lb. per sq. ft.*
Southern Standard Building Code (1958)	less than 30 ft.	10	25
	31 to 50 ft.	20	35
	51 to 99 ft.	24	45
	100 to 199 ft.	28	50

		Wind Pressure lb. per sq. ft.
North Carolina State Building Code (1958)	less than 50 ft.	20
	50 to 99 ft.	24
	100 to 199 ft.	28

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RECEIVED Oct. 30, 1959. Presented at the 14th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Pittsburgh, Pa., Oct. 12–15, 1959.

[5] BuY&D Navdocks TP-Te-3, 15 May, 1954, p. 10.
[6] New Standard Wind Load Requirements, J. P. Thompson, *Eng. News Record* p. 34 (Feb. 14, 1957).
[7] *Eng. News Record* p. 33 (Dec. 8, 1955).
[8] Same as 5, Appendix A.

Continuous Coating Color Preparation: Evaluation of Starch-Binder Coatings Prepared in the Thermal Cooker

G. E. LAUTERBACH

A PROCESS for making machine coating colors should be capable of producing coatings of uniform properties without batch-to-batch variations. In preparing starch binders for paper coatings, certain compromises must be made so that the finished coating has the properties required by the coating process and the paper grade. Of major importance is the fact that the high solids requirement of machine coaters is such that the amount of water in the finished coating does not allow the starch to be cooked at concentrations low enough to give entirely adequate dispersion. For example, 1.7% starch suspensions have been shown to be capable of absorbing all the water in a system upon heating (*1*). Agitation of the starch suspension during cooking helps disperse the swollen granules into smaller fragments. Since the amount of shearing action is likely to vary with the total batch volume, variability can be introduced as to the actual paste viscosity and, very likely, as to the degree of viscosity change when softeners, such as saop, are added to the coating.

This paper deals with a continuous starch cooker that appears to produce exceptionally clear (indicating high degree of dispersion) and uniform starch pastes.

The continuous starch cooker (*2*) manufactured by the Thermal Equipment Copr. (*3*), has gained acceptance by the gum-candy producers in North America and parts of Europe. This acceptance has been based on economy and ease of operation as well as the exceptionally clear gums produced at rather high solids. Formerly, starch used for jelly beans and gum drops was first cooked in open kettles and and then boiled for several hours to reduce the water content. With the thermal cooker, the candy ingredients are mixed at the consistency required for the process and then cooked at 220 to 230°F.

Exceptional dispersion of the starch (perhaps approaching the molecular level) is suggested by the improved clarity and shelf life of the gum confections so prepared. Optimum dispersion of the starch granule is desired for coating color preparations.

In dealing with a continuous starch cooker, the possibility of developing a continuous coating color preparation process is to be considered. In such a system, one approach would be to try to combine the steps of clay dispersion and binder preparation as has been done in some earlier batch processes (*4*). That the Thermal Cooker could be used in this way was indicated in our first trials in the manufacturer's demonstration unit.

Two starch processors, Penick and Ford and Clinton Corn Processing, have used the Thermal Cooker to prepare starch pastes for the paper industry. Penick and Ford, Clinton Corn Processing, and now National Starch and Chemical Co. have their own piping versions of the cooker which they recommend for wet end applications. More recently, work has been done by the starch companies in cooking starch and clay together. This phase of their work was done concurrently but independently of the work reported here. The material presented in this paper deals with cooking slurries of the complete coating formulations, including soap and caustic, in the Thermal Cooker.

The coatings prepared in the cooker performed as well on paper as identical formulations prepared in conventional starch kettles and kneaders. Improved pick resistance and higher viscosities were achieved. This, however, may be caused by cooking the starch in the presence of the soap and caustic rather than the use of the Thermal Cooker. That is, caustic aids starch cooking so that a more efficient adhesive is produced and also increases thickening with soap by providing additional reactive sites.

G. E. LAUTERBACH, Research Chemist, Paper and Converted Specialties Laboratory, Kimberly-Clark Corp. Neenah, Wis.

EXPERIMENTAL

Description of the cooker

The Thermal Cooker is produced in two sizes: the "production" model and the "laboratory" model. The stainless steel laboratory model, used in this study, is misnamed since it has the capacity to furnish all the coating required to coat one side of a production machine coater operating at fairly high speeds. In our pilot plant, maximum coating production was limited to 6 to 7 g.p.m. since the volume of steam available was inadequate to maintain the control temperature (230°F.) at higher rates. In most of the experiments, a rate of about 5 g.p.m. was used.

The unique feature of the Thermal unit is the cooking chamber. On the model used in this work, it is a horizontal, stainless steel cylinder about 20 in. long and $2^1/_2$ in. diam. A system of nozzles at one end of the cylinder is so directed that an axial stream of raw slurry converges with four impinging jets of steam. The turbulence produced by this configuration assures intimate mixing of the slurry ingredients and rapid heat transfer. Another advantage is that no constrictions are built in to inhibit the passage of fluid through the chamber. This permits the use of higher slurry concentrations and viscosities as well as allowing the passage of larger, dispersible lumps of material into the cooker with little or no chance for plugging the system. For example, rejected jelly beans, orange slices, or gum drops are easily redispersed.

The raw slurry is supplied to the cooking chamber through a stainless steel Bump positive displacement pump driven by a Reeves variable speed drive to deliver approximately 1 to 10 g.p.m. The slurry passes through the jets of steam and is driven to the other end of the chamber where it is forced downward through an opening in the wall of the cylinder into the discharge line.

A Honeywell controller recorder was added to maintain the temperature of the effluent at the central point (230 ± 2°F.) by acting on a Powers variable steam valve. Immediately downstream from the temperature probe is a Hancock valve furnished to regulate the pressure in the chamber. In this work, a back pressure of 20 p.s.i. was indicated on the gauge between the Powers valve and the cooking chamber.

Preparation of Coating Colors

The raw slurry, containing 100 parts KCS clay, 15 parts starch, 1 part soap, 0.3 part Calgon and 0.2 part NaOH, was dispersed by mild agitation. The amount of water used was that calculated to give the desired solids in the finished coating plus an allowance for dilution during cooking caused by condensate. The dilution allowance amounted to approximately 6 percentile units for the system and production rates used in this work. The slurry of the complete coating formu-

Table I. Performance of White Dextrin Coatings on a Groundwood Sheet (Wire Side)

Preparation	*Coating solids as applied*	*MacMichael viscosity as applied*	*Coat weight, lb.*	*Opacity*	*K.C. gloss*	*Rotary*		*Letter-press pick*	*Halftone*
						Rupture	*Pick*		
Cooker	55.7	87 at 29°C.	5.1	94.5	33.6	13.6	10.8	6.3	3.2
Kneader	55.0	57 at 28°C.	4.7	94.9	35.2	5.2	3.7	7.3	3.6
Kneader	55.4	66 at 29°C.	5.1	94.6	30.2	11.2	6.8	8.0	4.8

Table II

Preparation	15% binder	Coating solids as run	MacMichael viscosity	Coat weight, lb.	K.C. gloss W	K.C. gloss F	Rotary rupture W	Rotary rupture F	Rotary pick W	Rotary pick F	Letter-press pick W	Letter-press pick F
Cooker	White dextrin	W. 53.2 F. 54.4	66 at 32°C. 79 at 36°C.	13.4	36.8	35.4	21.0	18.2	17.8	15.0	1.0	1.0
Kneader	White dextrin	56.0	70 at 27°C.	13.0	37.4	34.6	18.6	16.2	14.4	13.2	1.0	1.7
Kneader	Hydroxyethylated starch	57.4	84 at 26°C.	16.8	42.4	41.6	22.8	23.2	18.4	13.4	1.0	1.0

lation is then allowed to stir for 10 to 20 min. longer with vertical mixing to assure a smooth suspension.

After the cooker is operating at the control temperature against cold water, the slurry is introduced by shifting a two-way valve in the supply line. An 8 to 10°F. temperature drop occurs immediately after switching to the slurry—even when the slurry is slightly warmer than the water used in the startup. Possibly, this is related to the energy required to dissolve the starch and disrupt the granule structure.

Upon leaving the discharge pipe, the coating is flashed to atmospheric pressure, thereby reducing the temperature to just below the boiling point of water. It may then be cooled or used immediately since significant cooling usually occurs on the coating train and in the piping.

Analytical methods

The coating colors were tested for solids content by oven drying at 105°C. and the viscosities measured with a MacMichael viscometer (1 cm. cylindrical bob, no. 26 wire, 40 r.p.m.) at room temperature and a Brookfield viscometer (100 r.p.m., no. 6 spindle, Model RVT) at 50.0°C. The weight of the coating on the experimental papers was calculated from the basis weight (25 × 38—500) and the difference in ash content of the coated and uncoated paper with allowance made for the clay ashing factor. Opacity measurements were taken with the Bausch & Lomb Opacimeter while the gloss of the supercalendered papers was determined with the Kimberly-Clark glossmeter (*5*). Pick and rupture resistance was measured by two methods. One method is described by W. W. Roehr (*6*) for rotary pick and rupture. In this procedure, pick resistance increases with the numerical value of the data. The other method, letterpress pick, is based upon visual grading of pick in a solid letterpress print made under controlled conditions on a small Chandler & Price press. Gradings from 0 to 10 indicate increasing pick.

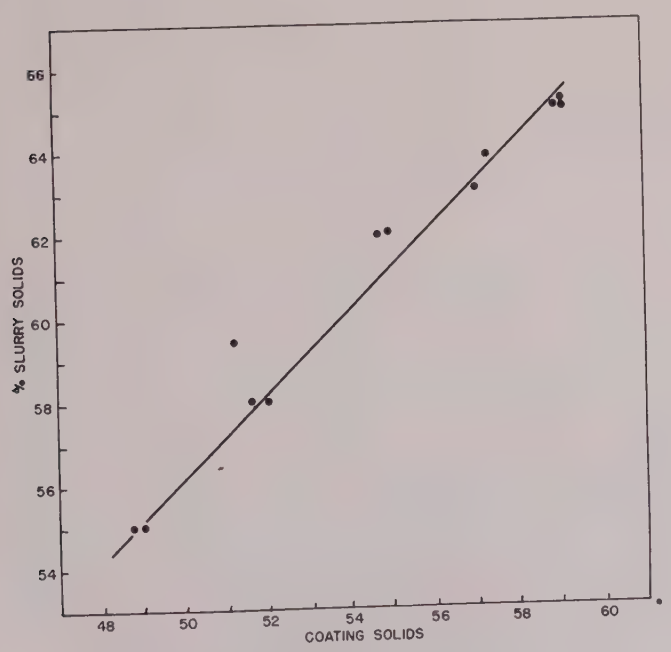

Fig. 1. Dilution by condensate

The printing quality of the coated papers is judged on the basis of the reproduction of a 50% halftone print made on a Chandler & Price press under controlled conditions of ink-film thickness and pressure. Gradings between 1 and 7 indicate an increasing number of skipped dots and poorer printing.

Comparison of Coatings Applied with a Laboratory KCM Roll Coater

Coatings prepared in the Thermal Cooker, as well as by kneading the cooked starch binder into the clay, were applied to a 40-lb. (25 × 38—500), 50% groundwood sheet by means of a small KCM roll coater using a 9-in, web. A commercial corn starch white dextrin was the binder used in this comparison. The wire side coated paper samples were conditioned to 50% R.H. at 72°F. before receiving three nips on a laboratory supercalender. The results of this experiment are given in Table I.

From these data two features are observed in the cooker-prepared coating: (1) the viscosity of the color is higher even though the solids were about the same as those of the kneader prepared colors; (2) pick resistance appears to be higher as indicated by both the rotary pick and letter press pick tests.

Gloss has not been affected by the manner of preparing the coating colors nor has the opacity. Printability may have been improved by cooker preparation as suggested by the slightly better halftone gradings. Thus, it may be concluded that the Thermal Cooker has no adverse effects and produces coatings equal to those prepared in kneaders but with somewhat improved pick resistance.

Comparison of Coatings Applied on a Pilot Plant KCM Coater

Two coatings were prepared in kneaders from 250-lb. batches of clay. One coating contained 15 parts corn white dextrin and the other 15 parts of an acid modified hydroxyethylated corn starch. A similar quantity of coating was prepared in the Thermal Cooker at 230°F. with the white dextrin binder. Both sides of a 50-lb. (25 × 38—500) groundwood free sheet, 30 in. wide, were coated at 400 f.p.m. on a KCM coater. The results of this experiment are summarized in Table II.

From these data it is observed again that cooker preparation improves pick and rupture resistance for the same binder type. Higher viscosity of the cooker prepared coating color was also observed. The dextrin coating prepared in the Thermal Cooker gave similar pick and rupture resistance at 13.4 lb. per ream to the hydroxyethylated starch coating at 16.8 lb. per ream prepared in the kneader. Typically, the hydroxyethylated starch binder gave higher gloss with the same supering. For identical formulations gloss was unaffected by the preparation process.

Table III

Caustic in slurry	Slurry solids	Coating solids	Brookfield at 50°C.	MacMichael
No	62.0	54.9	22.4	60 at 30°C.
Yes	62.0	54.8	32.8	87 at 31°C.
No	58.0	52.0	12.1	29 at 30°C.
Yes	58.0	51.6	14.0	38 at 33°C.

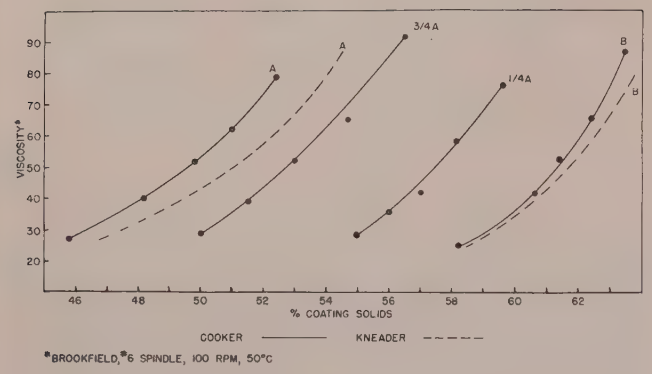

Fig. 2. Blended hydroxyethyl starches A and B, coating viscosity versus solids, 15% binder

Dilution of Colors by Steam Condensate

Injection of steam into the coating in the chamber of the Thermal Cooker causes some dilution of the material passing through. This dilution was examined over a fairly wide range of raw slurry consistencies and is summarized in Fig. 1. The amount of this dilution is a function of the steam supply and changes with the quality of steam entering the cooker. The manufacturer claims no dilution if dry steam is used.

The average difference between slurry and coating color solids was -6.3 ± 0.4 for the system as it was installed during this project. The presence of absence of caustic in the slurry did not affect the dilution of the coating but did affect the viscosity. This may be seen upon examining Table III. Coating cooked with the caustic displayed slightly higher viscosities than those adjusted to the same pH range after cooking. This is probably related to improved starch dispersion usually accompanying alkaline cooking.

Collection of Data for Coating Formulation

In order to obtain information so that solids and viscosities could be predicted for coatings to be used in larger trials, a series of coatings was prepared in the Thermal Cooker. Two viscosity grades of a commercial hydroxyethylated corn starch were blended in several ratios and used at 15 and 18% binder levels. The results are shown in Figs. 2 and 3. Figure 2 also indicates the relative displacement of the dilution curves of two coatings due to processing in the Thermal Cooker. These curves were obtained at 50.0°C. by averaging 5 to 6 Brookfield viscosity readings at each dilution.

Mill Trials

A larger cooker (5-in. diam. chamber) was purchased and installed in a book paper mill. The new cooker was similar to the smaller unit except that a 20 g.p.m. Moyno pump was used. The data supplied from Figs. 2 and 3 were used in the formulation of the starch blends used in the mill coatings. The solids and viscosities obtained were those predicted by the graphs. Dye was added to the raw slurry to match production standards. Paper of acceptable quality was obtained in these trials. No attempt was made to cool the coatings but cooling in the lines, tanks, and on the coater reduced the temperature to nearly normal for that coating press. The steam dilution was 3 to 4 percentile for the first trials but dropped to about 1 percentile on more extended operation.

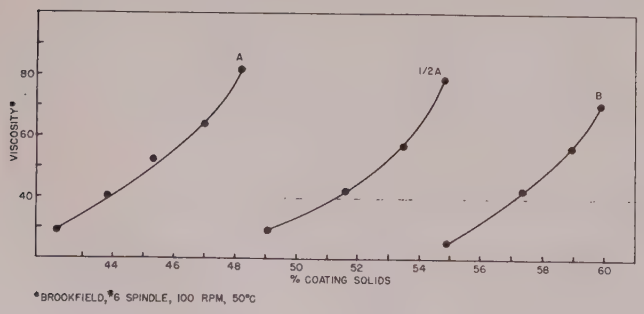

Fig. 3. Blended hydroxyethyl starches A and B, coating viscosity versus solids, 18% binder

CONCLUSION

The Thermal Cooker has been used to cook slurries of the complete coating color formulation (dyes included) which use starch binders. Acceptable performance of the paper coated with these colors was obtained with no operating difficulties occurring on the KCM coating presses used in this work. Clay dispersion in the laboratory and pilot plant was accomplished in the Thermal Cooker without requiring heavy mixing equipment. In the mill trials, clay slips prepared with and without kneaders were used without detectable differences in paper quality. If further experience verifies these findings, the cost of assembling color preparation systems could be reduced considerably.

The high temperature and shearing action produced by the impinging jets of steam in this cooker were quite effective in producing uniform dispersions of corn starch products. This is suggested not only by the clarity of the starch pastes and improved quality of gum candies but also by the higher viscosities and pick resistance of the coating colors containing soap. That starch pastes of the highest degree of starch dispersion also show the highest viscosity in the presence of soap (*6*) also supports this conclusion.

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Eleventh

Coating Conference

of the

Technical Association

of the

Pulp and Paper Industry

Edgewater Beach Hotel

Chicago, Ill.

May 23–25, 1960

Progress in Alkaline Pulping—1958

THE INSTITUTE OF PAPER CHEMISTRY*

This report continues the series (*1–12*) on the technical and topical literature reporting progress in alkaline pulping. It reviews the literature abstracted in the Abstract Bulletin of The Institute of Paper Chemistry during the calendar year 1958.

EXPANSION, MODERNIZATION, NEW MILLS

United States

Paper Mill News (*13*) presents a survey of expansion and modernization programs in U. S. and Canadian paper and pulp mills which have been completed in 1957 or which are projected for 1958–59.

Van Derveer and others (*14–17*) describe the new $17,750,000 bleached kraft paperboard mill of American Box Board Co. at Filer City, Mich. The addition has raised the total capacity of the plant to 550 tons per day. Interesting features of the mill include the new integrated kraft and neutral sulfite chemical recovery system, the addition of screen tailings from the kraft system to the NSSC cooked chips being fed to the refiners, and the five-stage bleach plant designed to produce pulp at 85 to 90 brightness with an expected yield of 45%.

Parker and others (*18–20*) describe the new mill of Dierks Paper Co. at Pine Bluff, Ark. The mill is producing 150 tons per day from sawmill chips and pulpwood logs.

Production has begun at International Paper Co.'s new mill in Pine Bluff, Ark. (*21*). The mill's daily capacity includes 375 tons of newsprint and 475 tons of bleached kraft board.

Ludwig (*22, 23*) describes the new $11 million bleached kraft pulp mill addition at the Lincoln, Me., mill of Eastern Corp. Among the interesting features of the new 175-tons-per day plant are a Kamyr continuous digester installed primarily for hardwood pulping, and the use of a Venturi scrubber and cyclone evaporator for fume recovery, and contact evaporation at the recovery boiler.

O'Donnell (*24*) describes the latest step in a program of modernization and expansion at the pulp mill of Halifax Paper Co., Inc., Roanoke Rapids, N. C., which is a seven-story recovery unit. It has the capacity to handle daily the black liquor from 550 tons of kraft pulp while producing a maximum of 203,000 lb. of steam per hour.

The new 500-ton boiler installation in the black liquor chemical recovery plant in the kraft mill of the Chesapeake Corp. is described (*25*).

Waters and others (*26–29*) describe the new mill of Rayonier, Inc. at Jesup, Ga. The mill is the company's second 300-ton chemical cellulose and wood pulp unit at the site.

The expansion program at the paper and pulp mills and auxiliary plants of St. Regis Paper Co. at Jacksonville, Fla., culminated in the start-up of a new paper machine in September, 1957 (*30*). The facilities of the mills are described in detail, covering wood handling, pulping, chemical recovery and liquor making, and general features of construction.

Waters and others (*31–34*) describe the new 300 ton-per- day bleached sulfate pulp mill of Gulf States Paper Corp. at Demopolis, Ala. The Kamyr continuous digester, bleach plant, and power and recovery plants are some of the features of the new plant which are described.

The new $30 million bleached kraft mill of Container Corp. of America at Brewton, Ala., is described (*35–37*). The mill is designed for a daily output of 300 tons of pulp or paperboard. The paper machine is a fourdrinier with a 216-in. wire.

Hatten (*38*) gives a description of the expanded kraft pulp and paper facilities recently completed at the Gair Division (Continental Can Co.) mill at Hodge, La.

Knight (*39*) reports on the Kamyr continuous digester recently installed at the Longview mill of Weyerhaeuser Co. and now in operation producing 140 tons per day of kraft pulp. The operation and instrumentation are described.

Sconce (*40*) reports on the new continuous kraft cooking and recovery system and new bleach plant started at the Camas, Wash., mill of Crown Zellerbach Corp. The increased facilities bring the total bleaching capacity of the mill to 885 tons per day.

Van Derveer and others (*41–44*) describe the new $22 million kraft pulp, paper, and board mill of Georgia-Pacific Paper Co. at Toledo, Ore. The mill's 262-in. fourdrinier, the largest kraft paper machine on the west coast, is designed to produce over 250 tons per day of kraft paper or board. The mill will obtain the major portion of its wood requirements in the form of chipped wood waste from the adjacent saw and plywood mills operated by the parent company, Georgia-Pacific Corp.

Canada

In the annual review number, *Candian Pulp and Paper Industry* (*45*) presents a review of progress in mills in the various provinces. *Pulp and Paper Magazine of Canada* (*46*) summarizes the expansion plans within the Canadian pulp and paper industry by presenting a list of 44 companies with projects underway in 1957 or contemplated for 1958 and 10 companies with potential, deferred, or abandoned projects.

Taylor (*47*) reports that an over-all survey of pulp

* The review for 1958 was prepared by J. R. Byrne, Research Assistant, under the direction of D. J. MacLaurin, Chief, Pulping and Papermaking Section, The Institute of Paper Chemistry, Appleton, Wis.

and paper mill expansions in Canada in 1958 show a decline in the number of large-scale capital projects anticipated for the future. The various Canadian mills with expansion programs are listed along with the cost, completion date, and a brief description of the project.

Glen (*48–50*) gives detailed descriptions of the expansion undertaken at the Dryden, Ont., mill of Dryden Paper Co., Ltd., which has increased production from 250 to 500 tons per day of bleached kraft pulp.

Some of the highlights of the 1957 program of modernization and expansion of Ontario-Minnesota Pulp and Paper Co., Ltd., are the start-up of a new newsprint machine at Kenora, installation of a kraft washing system at International Falls, and a new pulp distribution system at Fort Frances (*51*).

Johnston and others (*52–56*) describe the new bleached kraft pulp mill of Thurso Pulp and Paper Co. at Thurso, Que. The mill has a rated capacity of 200 tons per day to be produced from both hardwoods and softwoods.

A description is given (*57*) of the recent expansion and diversification at the MacMillan & Bloedel, Ltd., pulp and paper mill at Port Alberni, B. C.

Anglin and others (*58–62*) describe the new highly automated bleached sulfate pulp mill of British Columbia Forest Products, Ltd. at Crofton, B. C., being built at a cost of $46 million. Its designed capacity is 425 tons per day.

Knight (*63*) and *Paper Mill News* (*64*) describe the Elk Falls Division of Crown Zellerbach Canada, Ltd. The recent expansion included increasing the kraft mill capacity to 500 tons daily, the installation of a new combination kraft and newsprint machine, and the construction of a 175-ton-per-day bleach plant. Dyck (*65*) reports that sulfate pulp in shredded form is also produced at Elk Falls for shipment 1100 miles to Crown Zellerbach's Antioch, Calif., mill.

Paper Industry and other publications (*66–69*) give detailed descriptions of the Hinton, Alberta, mill of North Western Pulp & Power Ltd. McCarthy (*70*) describes the design and engineering features of the mill.

Europe

A description is given (*71*) of the first new kraft pulp mill to be built in Sweden for more than a quarter of a century. The new mill at Monsteras is being built for a new company, Skogsagarnas Cellulosa AB. The initial capacity of the mill will be 75,000 tons per year of unbleached and semibleached grades.

Esselin (*72*) reports on the current expansion program at the Papeteries de Gascogne kraft paper and bag mills which is aimed at increasing the daily production of kraft paper to 80 to 120 tons. A new black liquor recovery unit, an effluent disposal unit, and a new Yankee paper machine have been installed. The 50-cu. m. digesters are being gradually replaced by more modern units of 125-cu. m. capacity.

Australia

Baird (*73*) reports that the Maryvale pulp mill of Australian Paper Manufacturers Ltd., designed for a daily output of 90 air-dry tons of eucalypt kraft, has increased its capacity to 270 tons per day. The organization of a construction department to carry out the expansion and details of the new plan are described.

ALKALINE PULPING—GENERAL

Brief abstracts are given (*74*) of the papers presented at the 11th Alkaline Pulping Conference held in Charleston, S. C., on Nov. 5–7, 1957. Some of the topics were: shortwave ultraviolet absorption as a means of controlling kraft pulping, a slurry system for salt cake distribution, the use of additives in the clarification of white liquor, a new process for the manufacture of chlorine dioxide, cold soda pulping and the peroxide bleaching of cold soda pulp, and fiberizing semichemical pulps.

Nolan (*75*) predicts that the southern kraft mill of the future will use slash pine to manufacture bleached market pulp in the range of 85 to 90 G.E. brightness having a strength equal to that of unbleached grades. Bleaching will involve the following five stages: two chlorination and caustic extractions and a final chlorine dioxide treatment. The modern pulping system, involving continuous methods and expanded chip surfaces, will make it possible to obtain almost completely fiberized pulps in the digester at yields of 50% or higher.

Diehm (*76*) analyzes and compares the costs of different pulping processes. A table in which costs are presented according to fibrous raw materials, chemicals, and operating expenses shows the highest costs for bleached spruce sulfite and kraft pulps and the lowest costs for aspen NSSC and straw-lime corrugating media and aspen chemigroundwood.

Gati and Vamos (*77*) discuss the factors and considerations involved in the planning and construction of a straw pulp mill in Hungary. Among four possible processes by which straw can be pulped, the sulfate process is preferred for economic reasons. In addition to wheat straw, rice straw has given good results.

Banfill, *et al.* (*78*) outline a continuous weighing and moisture testing procedure which can handle large variations in digester chip charges and chip moisture which result from the use of mixed wood species. A meter called the Hygrotester Woodchip Moisture Meter is described. The differences in mill operations caused by low or high density deciduous woods are mentioned.

Samuels and Glennie (*79*) produced kraft pulp from Douglas-fir chips which included up to 20% bark. Chips containing 5% bark produced pulp no higher in dirt content than bark-free pulp, but the low yield obtained reduced the calculated market value of such chips to about 93% of that of bark-free chips. Chips containing 10% bark produced pulp of high dirt content as well as low yield. Centrifugal cleaning produced cleanliness nearly equal to that of bark-free pulp. The calculated market value of these chips was about 82% of bark-free chips. Chips containing 20% bark had a market value of 68% of that of the bark-free chips, but an acceptable cleanliness level could not be attained even with centrifugal cleaning.

Iwanow and Marker (*80*) prepared chips of three different sizes from two hardwoods and two softwoods and cooked them in laboratory autoclaves at 170°C. for certain lengths of time. Since chip penetra-

tion and digestion are a function of resin content, the optimum size of chips is expected to, and does, vary with each wood species and with the moisture content. Although good pulp can be obtained from hardwood and softwood mixtures, it is not recommended since it will result in overcooked and undercooked portions.

Gilles and Hunter (*81*) investigated the problem of pulp contaminated with charcoal or carbonized wood being produced in the mill. Evidence indicated that the charred wood came from a digester in which direct steam was being used to aid in loading the digester. It was recommended, therefore, that superheated steam never be introduced to chips before the cooking liquor is charged.

Kleinert and Joyce (*82*) investigated the ultraviolet absorption of alkali lignin and studied the applicability of the 205 mμ reading for measuring lignin in kraft cooking liquors. Estimating lignin in commercial brown stock wash waters was studied and the practical aspects of using this method as a means of control was discussed.

May and Peckham (*83*) investigated the contribution of re-using black liquor for dilution in kraft pulping to difficulties in attaining bleached pulps of high brightness. The active chemicals present in the black liquor were found to contribute to the pulping reactions roughly in proportion to their contribution to the total active alkali in the cook. The re-use of black liquor did not appear to have any deleterious effect on the strength properties or the bleaching characteristics of the pulp.

Jayme, *et al.*, (*84*) investigated the possibility of distinguishing bleached sulfate pulp from bleached sulfite pulp by means of fluorescence microscopy, that is, by the secondary fluorescence shown under ultraviolet light by pulp fibers treated with fluorescent dyes. Fibers fluorochromated with basic dyes did not permit a differentiation between sulfate and sulfite pulps. The spot application of a mixture of Rhodamine B extra and Brilliant Dianil Green permitted a distinction to be made. Sulfite pulps fluoresce pink and sulfate pulps blue. Similar results were obtained with a mixture of Rhodamine B and Thioflavin SFW.

THE COOKING PROCESS

Aronovsky and Lathrop (*85*) obtained a patent for a mechanochemical process for producing high yield pulp rich in pentosans from agricultural residues. The raw material is cooked in alkaline liquor at 90 to 100°C. and atmospheric pressure. Simultaneous with the chemical action, the fibrous material is subjected to vigorous noncutting impact blows while submerged in the pulping liquor.

Tishchenko and Rozenberger (*86*) carried out a series of pinewood kraft cooks at temperatures ranging from 195 to 235°C. to a permanganate hardness of 95 to 130 Bjorkman units. Higher cooking temperatures increased the delignification rate and decreased the pulp yield and viscosity. In the 175 to 200°C. range, the mechanical strength properties of beaten pulps remained practically unchanged; at 225° and above, the breaking length and bursting strength decreased rapidly.

Poppel (*87*) presents some data on the laboratory production of high-yield sulfate pulp. Sprucewood was pulped at 165°C. for 145 to 185 min., using 20 to 25% active alkali as Na_2O, followed by defibration with hot liquor in a ball mill. The pulp, obtained in 64% yield, showed physical and mechanical properties equivalent to those of ordinary kraft pulps.

Pulp production at Southern Paperboard Corp. was increased from 600 to 725 tons per day by the introduction of a high-yield system (*88*). The principal innovation is the moving of the stock from the blow tank through Claflin refiners (to break up knots) directly to the washers. Preknotters and complete refining of the stock before washing are avoided.

Iserlis (*89*) developed a high-yield kraft process by gradually decreasing the consumption of active alkali from 292 kg. per ton of pulp to 214 kg. per ton and by lowering the cooking temperature from 171 to 165°C. From this and a modified stock-handling procedure, the yield of pulp was increased from 86.3 kg. per cu. m. digester capacity to 100.8 kg. The mechanical strength properties of the high-yield pulp were generally higher than those of conventional kraft pulp.

Kachanov (*90*) reports that higher production at lower cost was the result of switching from conventional to high-yield pulping at the Kekhra, Russian pulp mill. The production cost per ton of pulp was lowered by 12 to 13% and the production capacity of the mill was increased by 17%.

Iwanow (*91*) reports that in the recently developed semihydrolysis process, most of the disadvantages which accompany prehydrolysis are eliminated. The entire process is carried out in a single rotary digester, requires low consumption of water and steam, and gives pulps of high yield.

A review of the literature by Finkel (*92*) indicates that prehydrolysis of annual plants and related materials improves the properties, yield, and economy of dissolving-grade kraft pulps but not those of sulfite pulps.

Nakano, *et al.* (*93*, *94*), investigated the manufacture of sulfate dissolving pulp using xylenesulfonate prehydrolysis. By using xylenesulfonate instead of water in the prehydrolysis step, a considerable amount of lignin is removed along with the pentosan, thus shortening the sulfate cooking time and improving the yield and quality of dissolving pulp obtained. Good results were obtained when beechwood chips were treated with an aqueous solution of 25% xylenesulfonate at pH 6.1 for 2 hr. at a maximum cooking temperature of 160°C.

Chêne, *et al.* (*95*), investigated the effect of cooking time, temperature, and soda concentration on the yield of raw, cooked, and classified wheat straw pulps and on their mechanical properties by applying statistical analysis of variance to data obtained. The soda concentration appeared to be the most important factor; its increase lowered the yield and porosity, but increased the mechanical properties.

Koch, *et al.* (*96*), evaluated spruce pine as a pulpwood source. Pulping and bleaching characteristics and pulp yields obtained are similar to those of southern pine.

Schafer, *et al.* (*97*), subjected beetle-killed Engelmann sprucewood to kraft pulping. A yield of 44.8% was obtained and the pulp was later bleached to a G.E. brightness of 76 by a three-stage process. Newsprint

papers well above average in strength and brightness were formed from the pulps.

Pustelnik and Surewicz (*98*) prepared kraft dissolving pulps from pinewood using a series of different cooking and refining methods. It was found that refining with hot alkali increases the alpha-cellulose content of the pulps and hot acid refining lowers the alpha-cellulose content and affects the rayon fiber strength. Pulps of 96–97% alpha-cellulose can be obtained by cold alkali refining. Pulps from acid-prehydrolyzed chips are characterized by high quality and homogeneity. Steam prehydrolysis gives higher yields and shortens production time, but does not permit the utilization of the hydrolyzate as in acid prehydrolysis.

Baczynska and Maj (*99*) prepared kraft pulps from *Pinus strobus* which had higher strength properties than ordinary pinewood pulps prepared under identical conditions. It is a relatively fast growing species, resistant to cold, and its use for reforestation should be considered.

Sihtola and Kaila (*100*) investigated the feasibility of regenerating the pine forests of Northern Finland with seedlings from Middle Finland. Trees from both areas were pulped by the kraft process and no significant differences were found in the yield or strength properties.

Bruun, *et al.* (*101*), describe the results of sulfate cooks of aspen and black alderwoods on the laboratory scale. The results are compared to data obtained from similar experiments on pine and gray alderwoods and previous results obtained for birchwood. The yields from the porous wood species passed through a maximum value that was highest for aspen, next highest for birch, and lowest for black alder. The aspen pulps also gave the lowest Roe number and the best color properties. Compared with pine, the porous wood species formed a separate class in respect to the time and degree of delignification and of yellowing.

Jensen (*102*) reviews the morphological characteristics and chemical composition of birchwood, and discusses the production and properties of chemical, high yield, semichemical, and mechanochemical pulps from birchwood.

Kossoi (*103*) established optimum kraft cooking conditions for birchwood alone, blended with larchwood and blended with pinewood. These conditions are 20% sodium hydroxide, 28% sulfidity, and a cooking temperature of 165 to 173°C. reached gradually during 2.5 hr.

Adamik (*104*) discusses the morphology and chemistry of *Ailanthus glandulosa*, the results of experimental cooks, and the properties of pulps obtained by the sulfate, bisulfite, and neutral sulfite processes.

Lauer (*105*) discusses the results obtained from the sulfate pulping of six hardwood species from the Amazon forests. A certain influence of the fiber structure was observed, especially of the ratio of wall thickness to fiber diameter. Lauer (*106*) also compared the sulfate pulps from mixtures of tropical hardwoods with those of industrially manufactured kraft pulps from mixtures of southern hardwoods and of hardwoods and pine. The comparison showed comparable breaking length and burst, but lower tear and fold for the tropical pulps. Lauer (*107*) made a few preliminary experiments to determine the suitability of the tropical hardwoods for high yield pulping. Pulps obtained using alkaline cooking liquor showed for comparable yields, higher tensile strength and tear than the neutral sulfite pulps. It was impossible to reach a brightness higher than 75% with the pulps from the alkaline digestion. The quality of the pulps corresponds to that of neutral sulfite semichemical pulps from soft maple, beech, or eucalyptus.

Overbeck and Agottani (*108*) subjected a mixture of eleven common Brazilian hardwoods to semicommercial kraft pulping under various conditions. Bleached pulps could be produced in yields of 42 to 50% by sharply limiting the cooking time at maximum temperature and by keeping the maximum temperature as low as possible. Strength properties were satisfactory and were only slightly affected by changes in cooking conditions.

Istas (*109*) reports on the research carried out to determine the possibility of exploitation for papermaking of the tropical hardwoods of the Belgian Congo as well as of papyrus, which grows abundantly there. Dissolving pulps containing 92 to 96% alpha-cellulose have been obtained from papyrus by the kraft process but in bleached yields on only 7%. Kraft pulping of the tropical hardwoods mixtures gave pulps of good mechanical properties which can be bleached to a brightness of 86%.

Gugnin (*110*) describes a recently developed method for the manufacture of kraft pulp from larchwood. Pulps obtained had a hardness of 138 to 142 permanganate units and a breaking length of 9000 to 10,000 m. Up to 90 kg. pulp were obtained from 1 cu. m. of digester capacity.

Bhat, *et al.* (*111*), report that results of experimental kraft pulping of *Cryptomeria japonica* indicate that the raw material should be useful in the commercial production of wrapping papers.

Centola (*112*) reviews the chemical composition and structure of eucalyptus woods, their present utilization, and possible future applications. Sulfite and kraft pulps from eucalyptus are characterized by high tensile and bursting strength, low folding endurance, and very low tearing strength. Their use in the manufacture of paper is limited, but they appear very satisfactory for the manufacture of viscose.

Stevens (*113*) reports that research at the Herty Foundation has demonstrated the suitability of 21 species of bamboo in producing paper and board. The two most promising pulping methods studied were the kraft and Raitt processes.

Chandhuri (*114*) reviews the two traditional methods for the alkaline cooking of bamboo: the one-stage cook and the two-stage cook. Considerable reduction in cooking time can be obtained through the use of a rapid-cycle process involving presteaming the chips and preheating the cooking liquor.

Gati and Vamos (*115*) report the results of research concerning the utilization of straw for papermaking carried out at the Hungarian Paper Industry Research Institute. Rice and rye straw were found to be the most suitable for pulping. For industrial production, the kraft process was found to be the best.

Escourrou (*116*) presents the results of investigations

conducted since 1943 on the cultivation and papermaking properties of sorghum. Only varieties with 10 to 20 chromosomes are suitable for papermaking. Whole stems are chopped and cooked with an alkaline liquor for 2 hr. under 1 kg. pressure. The pulps are then fiberized and cleaned in Centri•Cleaners. The unbleached pulp yield averages 45 to 55%. The breaking length of paper made of 100% sorghum pulp compares favorably with that of the best kraft papers.

Stuck (*117*) obtained a patent for a process for converting bagasse to a high-grade paper pulp which consists of a two-step digestion. The first digestion is done in a kraft-type solution which also contains 2 to 5% sodium peroxide under a saturated steam pressure of about 150 p.s.i. The unabsorbed solution is drained off, 1.0 to 2.5% sodium pyrophosphate peroxide is added and the second digestion carried out at 175 p.s.i. The digestion is terminated by suddenly releasing the pressure to cause an explosive expansion of the fiber bundles to pulp.

Ernst, *et al.* (*118*), present data on the chemical composition and pulping characteristics of bagasse samples from various areas for pulps from separated fibers and whole bagasse. Digestion with 13% chemicals for 1 hr. at 170°C. produced good pulps from separated bagasse fiber.

Jain (*119*) describes the pulping of bagasse and its role in the Indian pulp and paper industry. He also describes some characteristics of bagasse fiber and recommends the use of the kraft process over other methods.

Hapner (*120*) examined the fibers of *Cocos nucifera* and *Cycas rumphii* in regard to their papermaking potentialities. A kraft cook of *Cocos* gave a pulp of moderate strength in 51% yield. The practical utilization of this material is highly problematical. *Cycas* shows little differentiation between fibers and vessels and, although no cooks were made, its fibers would seem suitable for papermaking.

Barbasch (*121*) discusses the utilization of reed which grows in the Danube River delta. The sorted and chopped raw material contains 50 to 53% cellulose and 2.5 to 3.5% ash. Pulp yields of 45 to 49% are obtained by the kraft and Celdecor processes and of 55% by the sulfite process. Various kinds of writing and printing papers can be made from pulps containing up to 70% reed. Raikhman (*122*) reports on the work of the Institute of Research and Development of Paper, Pulp and Reed concerning the reed growing in the Danube Delta.

Voiret (*123*) reports that pulps of good quality can be obtained from monoicous hemp by the standard soda process or by a modification involving the preimpregnation of the material alternately under vacuum and pressure. Their properties were intermediary between those of kraft and sulfite softwood pulps.

Samuelson (*124*) points out some of the similarities between the chemistry of sulfate and sulfite cooks. The primary reaction in the kraft process involves scission of the molecular chain similar to that occurring during sulfite pulping. In both processes large quantities of organic acids are formed during the depolymerization of the wood carbohydrates. The organic excess sulfur present in spent sulfite liquor behaves in many respects like that in alkali lignin.

Christiansen and Legg (*125–126*) evaluated the result of controlled alkali concentration in kraft cooking on pulp quality. Injection of white liquor at 90 g. per l. effective alkali and 33.3% sulfidity was made to maintain constant concentration of effective alkali throughout the cooks. Compared with the conventional procedure, the injection technique incorporating Va-Purge and black liquor impregnation resulted in an increase of 5% in pulp strength and 20 to 40% in viscosity.

Dickerscheid (*127*) made pulping studies on southern pinewood to determine whether the active or effective alkali basis for applying cooking chemicals was more suitable for maintaining a uniform pulp bleachability level. The active alkali basis was found to be better for maintaining a uniform permanganate number pulp in the 15 to 35% sulfidity range; however, even that basis was not suitable above 35% sulfidity.

Bogomolov (*128*), in investigating the delignification mechanism in kraft and soda cooks, found that during the kraft process carboxyls and acid hydroxyls are formed, and that part of the methoxyl groups is split with the formation of methyl mercaptan and methanol.

Dryselius, *et al.* (*129*), studied the hydrolysis of cellobitol, lactitol, and maltitol in alkaline aqueous solutions at 170°C. as part of an investigation of the decomposition of carbohydrates during alkaline pulping. All substances were hydrolyzed at roughly comparable rates.

Yllner, *et al.* (*130*), studied the dissolution of lignin and the important carbohydrates of pinewood during kraft cooking. Delignification was independent of liquor concentration up to 150°C. but increased with higher concentration above this temperature. The dissolution of glucan and mannan was also independent of liquor concentration but xylan dissolution was highly dependent on it.

Knutsson and Stockman (*131*) studied the causes of the low strength and poor beating characteristics of kraft pulps prepared in a Kamyr continuous digester by experimental digestions in an autoclave, provided with a stirrer, in which cooked but nonfiberized kraft pulp was mechanically treated for various lengths of time. Marked deterioration of pulp quality occurred within a few minutes of treatment.

Kosaya (*132*) concluded from the experimental digestion of sprucewood chips of two different sizes separately and in mixtures that, in a continuous kraft process, good results may be obtained only with the use of fine chips (15–18 mm. in length).

WASHING AND SCREENING

Esilä and Hakkarainen (*133*) relate experiences with a three-stage brown stock washer installed at the Kemi Oy mill in Finland. Foaming caused by air contained in the black liquor was the biggest problem. In comparing the costs of four brown stock washing systems, a press stage followed by three filter stages was found to be the most economical.

Gugnin (*134*) reports a 20–25% increase in kraft pulp production as a result of reducing the washing time in diffusers to 4 to 6 hr. This reduction was obtained by switching from the paired diffuser method

to the "mixed" system in which all diffusers work together.

Grabovskii, *et al.* (*135*), report that kraft pulp washing in diffusers can be accelerated by preventing the concentration of the fibers on the false bottom and providing for a more uniform washing. This was accomplished by installing a conical discharging device and fine vertical chains in the center of the apparatus to provide a guiding and regulating surface.

Perlinski and Popiolek (*136*) give the results of a series of plant trials in which the efficiency of diffusers equipped with Markila-Brax screens was compared with that of conventional diffusers. When Markila-Brax screens alone are used, the black liquor removal time is shortened by 6 to 15%. The use of both types of screens shortens the drainage time by 33 to 38%.

THE LIQUOR CYCLE

Kleinert and Joyce (*137*) report that ultraviolet absorption measurements of kraft cooking liquors taken from the digester during cooking showed that the optical density values of liquor were directly proportional to its lignin concentration. During heating to cooking temperature, a straight-line relationship exists between optical density and the methoxyl content of the liquor. At cooking temperature, optical density increases faster than the methoxyl content indicating that, along with delignification, a partial demethoxylation occurs.

Mahannah (*138*) describes some of the features of the new chemical recovery unit at Halifax Paper Co., Roanoke Rapids, N. C., including the three-compartment Research-Cottrell electrostatic precipitator.

Owens (*139*) discusses the trends in recovery unit design which have included higher capacity, higher steam pressures, and wider application of labor-saving equipment. The average capacity of recovery units purchased in the past two years is as high as 330 tons.

Howe (*140*) discusses the change in furnace efficiency and operation which takes place when a recovery unit is overloaded. A 200-ton Combustion Engineering unit was studied, and the drop in efficiency was 10% as the load increased from rated capacity to 65% overload.

Western Precipitation Corp's. soda ash recovery process has been installed at Consolidated Water Power & Paper Co., Wisconsin Rapids, Wis. (*141*). The process avoids scale and corrosion troubles and eliminates the liberation of hydrogen sulfide during the evaporation step.

Ono and Isono (*142*) studied the glycerin and sodium stannate requirements of kraft black liquor analyzed by TAPPI Standard T 624 m-44. Glycerin may be omitted when determining sulfite contents of 4 g. per l. or less, or when the sample is reduced from 100 to 25 ml. In the presence of large amounts of sulfite, the use of 0.001 *M* sodium stannate is recommended as an antioxidant.

Philipp and Hoyme (*143*) developed a method for the quantitative determination of sulfide, free base, and carbonate in white and black kraft liquors. Sulfide is determined by direct titration in an ammoniacal medium with a standard zinc sulfate solution and Eriochome-Black T as indicator. Sodium hydroxide and sodium carbonate are determined by the usual titration with hydrochloric acid.

Domansky (*144*) states that none of the following methods—volumetric, gravimetric, conductometric, or potentiometric—are applicable to the analysis of the inorganic constituents of black liquor. Flame photometry is good because, in the highly diluted samples used, the interference of organic substances are eliminated; the determinations are accurate, and can be made within a few minutes.

Frey (*145*) describes the physical properties and chemical composition of black liquor from the kraft pulping of reed with emphasis on solids and ash contents and related variables.

Kooistra and Cobb (*146*) obtained a Canadian patent for a black liquor oxidizing means in which liquor drops on vertical screens, forms a thin film, and is oxidized by air passed between the screens. In order to minimize foaming, no air is passed through any body of liquor.

Using a pilot-scale black liquor oxidization tower under rigorously controlled flow conditions, Murray (*147*) found that the capacity coefficients increase with increase in liquor-flow rate and are virtually unaffected by changes in air-flow rate when this is sufficiently high to provide adequate oxygen for the reaction.

Ziegelmeyer and Feischl (*148*) confirmed that, during the oxidation of black liquor, 2 moles of sodium sulfide react with 2 moles of molecular oxygen in the presence of 1 mole of water to yield 2 moles of sodium hydroxide and 1 mole of sodium thiosulfate with the consumption of 215 kg. cal. of heat.

Stickney (*149*) discusses the power, steam, and by-product fuel relationships in integrated kraft mills. Some of the topics are the use of bark as a fuel, methods of burning bark and black liquor, and additional power requirements.

Schoeffel and Barton (*150*) obtained a Canadian patent for a black liquor regeneration process which permits as much pulp washing as needed and which requires substantially no sodium or sulfur make-up.

Shogenji and Mita (*151*) studied the applicability of kraft white liquor obtained from spent sulfite liquor smelt to the pulping of knotter rejects from sulfite mills. Pulp yield and quality were better than those obtained on cooking the rejects by the soda process with equivalent alkali consumption.

Badger and Lindsay (*152*) present their annual review of the literature published on the subject of evaporation.

Florine and Dedert (*153*) recommend that future expansion requirements be considered when planning a new evaporator since small increases in capacity later on become very expensive.

Tomlinson and Tomlinson (*154*) obtained a patent for a method and apparatus for recovering heat and chemicals from black liquor which involves concentrating the liquor and absorbing gaseous sulfur oxides therein by contact with hot flue gases, centrifugally separating residual liquor entrained in the flue gases, passing the flue gases through a fume recovery zone in contact with a recirculated aqueous liquid, withdrawing the fume from the zone, adding make-up

water to the aqueous liquid, concentrating the liquid, mixing it with the residual liquor, and burning the concentrated residual liquor.

Owens (*155*) obtained a patent for a liquor and temperature control for an apparatus in which black liquor is evaporated in direct contact with hot waste gases and then passed into a recovery furnace.

Stacey (*156*) describes a soda recovery furnace using a venturi spraying black liquor as both an evaporator and a fume scrubber. Operational data indicate that chemical reclamation from the furnace gases may be expected to exceed 85%.

Beaver (*157*) obtained a patent for a device in which gases from black liquor combustions are cleaned and cooled by passing them past exposed electrodes which collect material and recover heat. A stream of air is directed over a portion of the electrodes to pick up heat. The material collected is dropped into a bath of black liquor which is thereby fortified prior to being burned.

Cas (*158*, *159*), obtained a U. S. and Canadian patent for an apparatus having shearing blades which break the stream of smelt as it flows into the dissolving tank thus avoiding explosive steam formation.

Gray, *et al.* (*160*) obtained a U. S. patent for a method of regenerating pulping liquors which is particularly suitable in conjunction with a two-stage acid-alkaline digestion system. The two effluents are combined and burned to produce a single smelt and part of the sulfide is eliminated. A portion of the smelt is then causticized to form alkaline cooking liquor. The other portion is carbonated and the sodium sulfide is eliminated completely. The resulting liquor is sulfited to form acid sulfite digestion liquor.

Gray and Crosby (*161*) obtained a Canadian patent for a process of producing alkaline pulping liquor from smelt in which the smelt is contacted with a cation-exchange resin having phenolic hydroxyl and carboxylic exchange centers in hydrogen form to evolve hydrogen sulfide and carbon dioxide and absorb sodium. The resin is then contacted with carbon dioxide at 2 to 50 atm. thus forming a solution of sodium bicarbonate which may then be treated in the usual manner.

Parkinson (*162*) reports that the pumping of dregs into the lime mud system has resulted in considerable saving in lime rock makeup. One disadvantage is the reduced causticity of the reburned lime, indicating dead load buildup.

Rothrock (*163*) reports that mill operating data indicated that a higher causticizing efficiency was obtained in a system using green liquor clarification as compared with a system using single stage mud washing only. The tests made to find the reason for the higher efficiency are described and the observations made as a result of the tests are summarized.

Hellstrom (*164*) obtained a patent for a causticizing apparatus which consists of two or three vessels connected vertically in series. The reaction mixture travels continuously through the vessels and the causticized solution and calcium carbonate sludge are withdrawn continuously from the lowermost vessel.

Kubelka, *et al.* (*165*), carried out experiments to determine the effect of silica on the causticization of green liquors, and on the sedimentation rate in white liquors. The sedimentation rate increased with increasing amounts of silica from 30 cm. per hr. for liquor containing no silica to 82 cm. per hr. for liquor containing 21.3 g. per l. of silica. Similar results were obtained with green liquor from reed pulping containing 14 g. per l. of silica. The increase is attributed to the formation of insoluble calcium silicate which favors the aggregation of particles.

Stevens and Wilkins (*166*) obtained a patent for a liquor reclaiming process in which the black liquor is subjected to a conventional recovery operation except that the amount of salt cake added is sufficient only to make up for lost alkali. Hydrogen sulfide is then added to make up the lost sulfur.

Ehrnrooth (*167*) found that 50 to 70% of the dirt particles found in the white liquor coming from the Dorr clarifiers can be removed by hydracyclones. However, silica, iron sulfide, and carbon cannot be removed in this manner.

Pavlick and McPherson (*168*) report on the use of flocculants to increase the rate of white liquor clarification and to better the efficiency of the sludge filter. A 1% solution of Separan 2610 added at the rate of 80 p.p.m. to the individual settling tanks gave the best settling rate and indicated that clarification of white liquors can be speeded up considerably.

Giesen (*169*) obtained a patent for a process of recovering lignin from black liquor where, in the first stage, the liquor is saturated with carbon dioxide at room temperature and under 20 atm. pressure, and in the second stage the liquor is treated with carbon dioxide at the same pressure and at a temperature of 100 to 120°C. to precipitate the lignin.

Copenhaver, *et al.* (*170*), obtained a patent for a process for recovering acetic acid in which the concentrated black liquor is acidified to liberate the acetic acid which is then extracted with methyl ethyl ketone.

Othmer (*171*) discusses some of the acetic acid recovery methods in use and states that more acetic acid is wasted in the black liquors of the pulping industry than is now used in the world chemical industry. Two possible recovery processes which could be applied to the pulping industry are described.

Wier and Diephuis (*172*) outline the growth and value of crude sulfate turpentine and point out some of the factors in a good recovery for maximum yields.

Cisney and Wethern (*173*) obtained a patent for a method of producing dimethyl sulfide in which elemental sulfur is added to black liquor which is then heated to 150 to 500°C. The dimethyl sulfide is then separated and the spent liquor evaporated and burned.

Meyer and Coma (*174*) report that a pilot plant designed to produce nearly 2,000,000 lb. per yr. of dimethyl sulfide from black liquor is now in operation at the Crown Zellerbach Corp. laboratories in Camas, Wash. The heated sulfur and black liquor mixture is cooled and the pressure reduced to the point at which the bulk of the dimethyl sulfide is in the vapor phase. It is separated and the dimethyl sulfide removed and purified. Yields of 60 lb. per ton of pulp are obtained.

STEAM AND AIR POLLUTION

Tanaka, *et al.* (*175*), report on a process which uses

scrap iron or aluminum to reduce the color intensity and the B.O.D. of kraft mill waste liquors. The scrap is dissolved in the waste liquor from the bleaching process and then mixed with the pulping waste. The ferric or aluminum hydroxide produced absorbs and precipitates organic colloids and adsorbs coloring matter from the waste liquors.

Pearman and Burns (*176–177*) describe the activated-sludge waste plant of West Virginia Pulp & Paper Co. at Covington. Operating data and problems encountered in the first year of operation of the plant are summarized. The plant has a design capacity of 16 million gal. per day, about two-thirds of the total waste flow from the mill.

Results of experiments designed to determine the effect of the toxicity to minnows of kraft mill effluents carried out by Lubet and Sechet (*178*) indicate that the absence of fish from polluted streams is not due to the toxicity of effluent chemicals but to the fact that fish desert polluted streams. Therefore, the absence of fish is not a reliable index of pollution. Microbiological population studies appeared to furnish a more accurate and reliable criterion.

Marczek and Zielinski (*179*) present the results of chemical and biological analyses of kraft mill effluents at different purification stages—with and without the addition of nutrient medium and with or without addition of 20% of waste from the diffusers. The purified effluents with nutrients added showed the lowest B.O.D., the same effluent without the nutrients the highest. The activated sludge receiving the most polluted material showed the highest number of organisms.

Berthier, *et al.* (*180*), analyzed black liquor samples from kraft cooks of hardwood, softwood, and wheat straw. Mineral and organic contents did not differ significantly, but black liquor from hardwood pulp had a color intensity twice that of liquor from softwood pulp and black liquor from straw pulp had a very high B.O.D. The concentration of turpentine was below the toxicity level.

Richardson (*181*) obtained a patent for a process by which air and stream pollution are prevented by contacting the lime kiln stack gases with weak black liquor to remove the major portion of the suspended compounds from the gases and to precipitate the major portion of the lignin-containing organic solids from the black liquor.

Lardieri (*182*) summarizes the results obtained in a survey of the kraft pulping industry by the National Council for Stream Improvement covering disposal of airborne effluents within the industry. It is concluded that the kraft industry does not have a critical air pollution problem at this time.

Meuly and Tremaine (*183*) obtained a patent for a treatment designed to abate alkaline pulping malodors which consists of adding to the digester charge 1 to 100 p.p.m. of a mixture of organic compounds, such as *n*-butyraldehyde, pyridine, isoborneol, geraniol, benzophenone, and ionone.

Gearhart and Thompson (*184*) patented a process for reducing alkaline pulping odors which incorporates a mixture of aniline and N,N′-di-*sec*-butyl-*p*-phenylenediamine in the cooking liquor.

Limerick (*185*) received a patent for an odor-abatement process which consists of mixing the scrubbed effluent gases with 10 to 100 p.p.m. of ozone for at least 2 sec. before discharging them to the atmosphere.

Colombo, *et al.* (*186*), developed an economical method of deodorization in which the effluent is oxidized with air using an air:acidified effluent ratio of 120:1. An almost complete oxidation of hydrogen sulfide and over 50% oxidation of mercaptan was obtained. An additional treatment with chlorine removed the residual gases.

Wright (*187*) discusses the financial and technical aspects of a completely odorless kraft mill. The price is made up of three parts—initial down payment, direct installment payments, and indirect installment charges. Technical aspects which would have to be studied are the kraft operating sequence, dust emission, odor release, and odor control and analysis.

Schneider (*188*) has modified a process which has been found successful in handling an air pollution problem involving sulfur compounds for application to terpenes, mercaptans, and sulfides.

Maksimov (*189*) presents a number of measures to counteract the release of obnoxious substances from kraft mills. They are better leakproofing and ventilation systems, automation of processes related to the preparation and transfer of toxic chemicals, periodical analysis of the air in the mills, and the installation of a black liquor oxidation system.

BLEACHING

A description is given (*190*) of the new seven-stage bleach plant recently installed at the Karlsborg kraft pulp mill of the state-owned Swedish forest industry group, Statens Skogsindustrie. The bleach plant has an annual capacity of 60,000 tons, nearly half of the total annual pulp production of the mill.

Bureau (*191*) gives a brief and nontechnical description of bleaching which covers a definition of bleaching, the basic reactions involved, and hypochlorite and multistage bleaching.

Rue (*192*) reviews some of the stages in the development of bleaching and predicts that future trends will continue toward super brightness, super cleanliness, super strength, use of peroxides for bleaching sulfate pulps, and design of bleaching equipment to combine the various bleaching stages in any desired sequence.

Lawrence and Salisbury (*193*) obtained a patent for a six-stage bleaching process (CHEHEH) in which, after the fourth stage, the pH of the pulp is reduced to 2 to 5 by addition of nonreducing mineral acids or the filtrate from the previous chlorination stage.

Fennell (*194*) obtained a Canadian patent for a multistage bleaching process for kraft pulp which obtains maximum final brightness by critical control of total alkalinity of intermediate caustic extractions.

Marpillero (*195*) obtained a patent for a method of carrying out a chlorine dioxide bleaching stage consisting of contacting an aqueous suspension of pulp with sodium chlorate in the presence of a vanadium, molybdenum, or tin catalyst and a promoter.

Stone and Matarese (*196*) patented a pulp bleaching process in which chlorine dioxide and chlorine are combined in the first stage to obtain good brightness and strength retention at a subsequent saving in the amount of chlorine expended.

Rapson and Anderson (*197*) describe a new three-stage sequence which bleaches kraft pulp to 85 to 87 G.E. brightness with good strength retention and moderate color reversion. It involves including a small amount of chlorine dioxide with the chlorine in the chlorination stage and some chlorine with the caustic soda in the extraction stage. Chlorine dioxide is the third stage.

CORROSION

Kesler (*198*) presents the supplement to the bibliography of alkaline digester corrosion which includes annotated references from 1956 and 1957.

Wegerif (*199*) summarizes the experiences at the Harmac, B. C. Division of MacMillan and Bloedel, Ltd. regarding the cause, repair, and prevention of digester corrosion. It has been established that the corrosion is due largely to hot plate boiling during charging of chips and liquor. The application of corrosion-resistant materials to the affected areas has been adopted as one method for the prevention of corrosion.

Roald (*200*) studied 20 different steel specimens exposed in two kraft mill digesters. Test results confirmed the effect of silicon in increasing the digester corrosion rate. Other constituents normally present in low carbon steel have no appreciable effect on the corrosion rate.

Kesler and Bakken (*201*) investigated the effect of the presence of appreciable quantities of sodium chloride, sodium sulfate, and sodium carbonate in kraft white liquor on the corrosion rate of mild steel in white liquor. The results of weight loss tests were correlated with the corrosivity of the liquor, using Roald's corrosivity equation. In liquors where the equation could validly be applied (liquor containing more than 1 g. per l. of sodium sulfite) the three chemicals appeared to cause increased corrosion with increased liquor corrosivity.

Uusitalo (*202*) reports that potential versus time and polarization curves indicate that the concentration of sodium hydroxide and sodiumm onosulfide present in normal kraft cooking liquors are sufficient to cause strong digester corrosion under unfavorable conditions.

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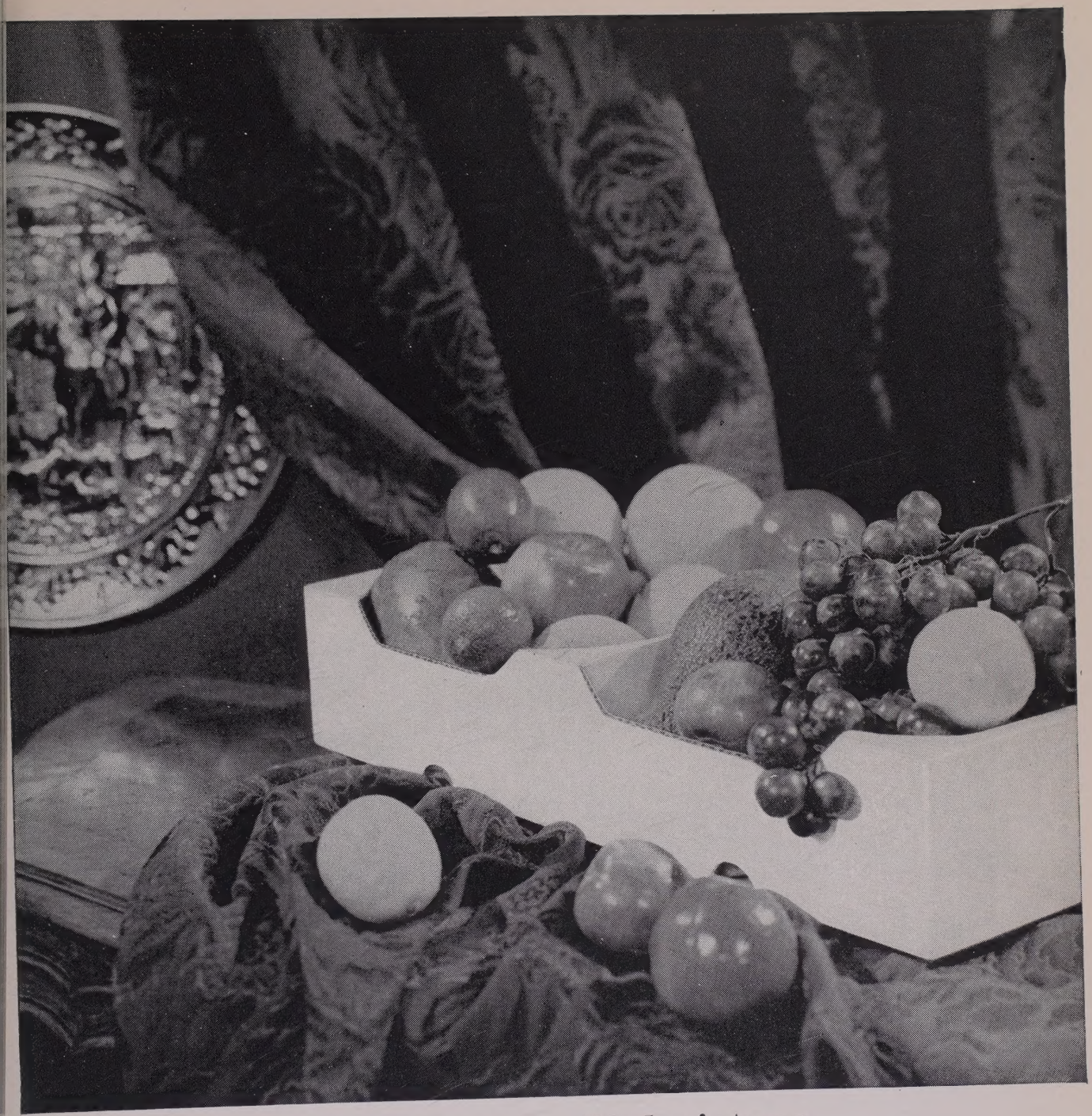

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